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NATIONAL ACADEMY OF SCIENCES.

VOL. VI.

FIRST MEMOIR.

ON THE CAPTURE OF COMETS BY PLANETS, ESPECIALLY THEIR CAPTURE BY JUPITER.

ON THE CAPTURE OF COMETS BY PLANETS, ESPECIALLY THEIR CAPTURE BY JUPITER.

By H. A. Newton.

1. Some years ago I obtained and published* a formula expressing in simple terms the total result of the action of a planet in increasing or diminishing the velocity of a comet or small body that passes near the planet. This formula is practically a modification of the integral of energy, the smaller terms in the perturbing function being omitted. A very brief and partial treatment of it was presented to the British Association for the Advancement of Science in 1879, at its Sheffield meeting.† Within the last two or three years several astronomers have made special study of the manner of Jupiter's action in changing the orbits of comets that pass very near him. M. Tisserand has given us an expression connecting the major axis, inclination and parameter of the orbit described before coming near to Jupiter with the corresponding elements of the orbit after leaving the neighborhood of the planet.‡ M. Schulhof has applied the formula of M. Tisserand as a criterion for determining the possible identity of various comets whose orbits pass near to Jupiter's orbit.§ Messrs. Seeliger, Callandreau, and others have continued these investigations. The interest thus shown in the problem has led me to resume the study of the subject, and to work out the results of the formula obtained by me in 1878 more fully than they have been hitherto developed.

2. One of the remarkable distinctions between the comets of long (or infinite) periods, and those of short periods, is that the orbits of the latter have almost without exception direct motions and small inclinations to the plane of the ecliptic, while the orbits of the former have all possible inclinations between 0° and 180°. At first sight this seems to imply that the two groups of comets are radically distinct in origin or nature one from the other. The most natural line of investigation therefore is the effect of perturbations in bringing or not bringing the comets to move with the planet after the perturbation.

3. The algebraic processes by which was obtained the formula for the change of energy which a small body experiences from passing near a planet were given in the article cited, and they need not be here reproduced. The following was the resulting equation, viz:

$$\triangle = -\frac{4mfa^2v_1 \cos\varphi \sin\alpha}{pr}, \qquad (1)$$

and it was obtained from the general differential equations of motion by making assumptions not greatly differing from those used in obtaining Laplace's well-known theorem, that a sphere of suitable magnitude may be described about the planet as a center and that for a tolerable first approximation the comet may be regarded as moving when without this sphere in a conic section of which the sun is the focus, and as moving when within the sphere in a conic section (an hyperbola) of which the planet is the focus. In other words, only perturbations of the first order of

* American Journal of Science, III. Vol. xvi. p. 175. 1878.

† Report, 1879, p. 274.

‡ Sur la théorie de la capture des comètes périodiques, Bull. Astron., Tome vi, juin and juillet, 1889.

§ Notes sur quelques Comètes a courte période, Astron. Nachrichten, No. 2961.

magnitude are taken account of. A comet is treated throughout this paper as a small indivisible body whose mass may be neglected.

4. *Notation.*—The symbols used in (1) and also other symbols which I shall have occasion to use may be thus defined:

Let $\mathfrak{C}_1$ = orbit of the comet about the sun before the comet comes under the appreciable action of the planet;

$\mathfrak{C}$ = orbit of the comet about the sun after perturbation by the planet;

C = hyperbolic orbit of the comet relative to Jupiter when near the planet;

$\mathfrak{J}$ = elliptic orbit of Jupiter about the sun;

A = point on $\mathfrak{C}_1$ which is nearest to $\mathfrak{J}$;

E = point on $\mathfrak{J}$ which is nearest to $\mathfrak{C}_1$;

d = length of the straight line EA being the perpendicular distance between the orbits at their nearest approach;

ω = angle between the tangent of $\mathfrak{C}_1$ at A and the tangent to $\mathfrak{J}$ at E;

h = distance which the planet has yet to pass over to reach E when the comet is at A (h may be negative);

m = mass of the planet, sun's mass = unity;

a = unit of distance, in general the mean distance of the earth from the sun;

f = sun's attractive force at the unit of distance;

v_1 = planet's velocity in its orbit at E;

$v_\circ$ = comet's velocity in its orbit C when the comet enters the sphere of Jupiter's perceptible influence;

v = comet's velocity at A relative to the sun;

$s = r_\circ / r_1$;

$\bar{a}_1$ = semiaxis major of $\mathfrak{C}_1$ (negative if $\mathfrak{C}_1$ is an hyperbola);

$\bar{a}$ = semiaxis major of $\mathfrak{C}$ (negative if $\mathfrak{C}$ is an hyperbola);

p = perpendicular from the planet upon asymptote to C;

α = acute angle between the transverse axis of C and the asymptote to C.

φ = angle between the tangent to $\mathfrak{J}$ at O (drawn in the direction of the planet's motion) and the line from the planet to the vertices and center of C;

A = semitransverse axis of C;

B = semiconjugate axis of C (hence equal to p);

r = distance of the planet from the sun;

r_1 = distance of the comet from the sun;

$r_\circ$ = distance of the comet from the planet;

ρ_1 and ρ = distances of the comet from the sun at selected epochs before and after perturbation;

u_1 and u = velocities of the comet at the selected epochs;

$\triangle$ = increase which $v^2 - \frac{2fa^2}{r_1} - \frac{2mfa^2}{r_\circ}$ receives by the planet's action during the whole period in which the comet is passing near to Jupiter.

5. If we assume two epochs, one before and one after the perturbation, at which the comet is equally distant from the planet, the term $2mfa^2/r_\circ$ is the same at both instants, and it disappears from the value of $\triangle$. Therefore

$$\triangle = u^2 - \frac{2fa^2}{\rho} - u_1^2 + \frac{2fa^2}{\rho_1}.$$

But the well-known formulas from the law of gravitation,

$$u_1^2 = 2fa^2\left(\frac{1}{\rho_1} - \frac{1}{2\bar{a}_1}\right),$$

and

$$u^2 = 2fa^2\left(\frac{1}{\rho} - \frac{1}{2\bar{a}}\right);$$

give

$$\triangle = fa^2\left(\frac{1}{\bar{a}_1} - \frac{1}{\bar{a}}\right),$$

that is, from (1) $\frac{1}{\bar{a}_1} - \frac{1}{\bar{a}} = -\frac{4m\cos\varphi\sin\alpha}{ps}$.

This equation is valid whatever be a, the major axis of the orbit $\mathfrak{C}$, and may be used to determine the major axis of either orbit from the elements of the other. My present purpose is, however, to study the action of Jupiter in changing orbits that are originally parabolas, and hence in general a, will be taken infinite. In that case

$$a = \frac{ps}{4m \cos \varphi \sin \alpha}. \tag{2}$$

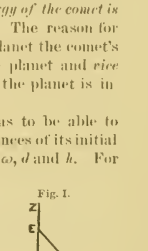
It will be found that the second number of (2) depends on ω, d and h, and these are known quantities when the elements of $\mathfrak{C}$, and $\mathfrak{J}$ are given. The use of the equation is moreover greatly simplified and enhanced by the fact that the plane of the planet's orbit is involved only in so far as that it must contain the tangent to $\mathfrak{J}$ at E.

6. In the second member of (2) all the factors are positive except $\cos \varphi$, hence, if $\varphi < \frac{1}{2}\pi$, a is positive and the orbit $\mathfrak{C}$ is an ellipse; but, if $\varphi > \frac{1}{2}\pi$, a is negative and $\mathfrak{C}$ is an hyperbola. This result may be thus expressed: *if the comet passes in front of Jupiter the kinetic energy of the comet is diminished; if it passes behind the planet the kinetic energy of the comet is increased.* The reason for this may also be given in general language. If the comet passes in front of the planet the comet's attraction increases the velocity, and hence increases the kinetic energy of the planet and *vice versa*. But the total energy of the two bodies is constant; so that when that of the planet is increased, that of the comet is diminished and *vice versa*.

7. It is desirable now to transform the value of a given in equation (2) so as to be able to determine the major axis of the new orbit of the comet directly from the circumstances of its initial approach to the planet before perturbation; in other words, to find a in terms of ω, d and h. For this we must find in terms of ω, d and h, values for s, p, α and φ.

8. *To find s.*—In Fig. 1 let A and E represent the two points A and E as defined above (Art. 4), and the line AE represent d. Let AY be the tangent to $\mathfrak{C}$, at A, and EO the tangent to $\mathfrak{J}$ at E. It is an admissible supposition that the planet is describing the *straight* line OE, and that the comet in its unperturbed orbit is describing the *straight* line YA. At some certain moment the line joining the planet and the unperturbed comet must evidently be perpendicular to OE. Let OY be the line joining the bodies at that moment, so that the planet is at O when the comet is at Y, and EOY is a right angle. Instead, however, of supposing the planet to move from O toward E we may apply an equal, opposite motion to the comet, and consider the planet to remain at rest at O. Draw AC parallel to EO and make AB equal to the distance described by the planet during the time that the comet is moving from Y to A. Join YB. Then since YA and BA represent in direction and magnitude the motions of the two bodies in a given interval, the third side YB of the triangle represents in magnitude and direction the motion of the comet relative to the planet. The angle YAB is the angle ω, and the three sides of the triangle YA, YB, and BA are proportional to r, $r_\odot$ and $r_\jmath$. Let the angle YBC be θ; then from the triangle YAB we have

Fig. 1.



$$r_\odot{}^2 = r_\jmath{}^2 - 2v_\jmath r \cos \omega + r^2,$$

and

$$r : r_\jmath :: \sin \theta : \sin (\theta - \omega) : \sin \omega. \tag{3}$$

Since r and $v_\jmath$ can be computed from the given elements of the orbits of the planet and comet, we may readily compute from ω the value of s, or $r_\odot \, v_\jmath$. But if the planet is at its mean distance from the sun, and the comet's orbit is parabolic, $r^2 = 2r_\jmath{}^2$, and we have

$$s^2 = 3 - 2\sqrt{2} \cos \omega. \tag{4}$$

Also from the triangle

$$2r_\jmath{}^2 = r_\odot{}^2 + 2r_\odot r_\jmath \cos \theta + r_\jmath{}^2,$$

or

$$2s \cos \theta = 1 - s^2. \tag{5}$$

9. *To find p.*—The planet being regarded at rest at O and the *relative* unperturbed motion of the comet being along YB, this line may within admissible limits of error be treated as one asymptote of the relative orbit C. The perpendicular from O upon YB will then be by definition (Art. 4) the line p. Draw OX from O perpendicular to OY and OE, and let these three lines be coördinate

axes. Let the line AB meet the plane XOY in C. Join OC, let fall OD perpendicular to YB, and join CD. Since EA is perpendicular to AY and also to EO, and so to its parallel line AC, therefore it is perpendicular to the plane YAC. Hence OC, parallel to EA is perpendicular to the plane, and so perpendicular to CD. Again, CDY is a right angle; for $OD^2+DY^2=OY^2=OC^2+CY^2$, and $OD^2=OC^2+DC^2$. Hence, $DC^2+DY^2=CY^2$, and consequently CDY is a right angle.

The quantity h is the line BC; for h is the distance which the planet, when the comet is at A, has yet to pass over before reaching E. But the comet was at Y when the planet was at O, and the planet describes BA, while the comet describes YA, leaving BC as the distance yet to be described, or h. But the angle CBD is θ, so that we have

$$p^2 = OD^2 = OC^2 + CD^2 = d^2 + h^2 \sin^2 \theta. \tag{6}$$

10. *To find* α.—The angle α is the acute angle between the asymptote and the transverse axis of the hyperbola, and hence from the nature of the hyperbola $\tan \alpha = B/A$. By known formulas we have, if the planet is at its mean distance

$$v_\prime^2 = 2\mu a^2\left(\frac{1}{r} - \frac{1}{2r}\right),$$

$$v_\bigcirc^2 = 2m\mu a^2\left(\frac{1}{\alpha} + \frac{1}{2A}\right).$$

Therefore

$$\frac{v_\bigcirc^2}{v_\prime^2} = \frac{mr}{A}, \text{ or } A = \frac{mr}{s^2}.$$

Hence from (6)

$$\tan \alpha = \frac{B}{A} = \frac{p}{A} = \frac{s^2 (d^2 + h^2 \sin^2 \theta)^{\frac{1}{2}}}{mr}. \tag{7}$$

11. *To find* φ.—The orbit of the comet relative to Jupiter lies in the plane YOB. Let i be the inclination of the plane YOB to YOX, measured positive from x positive to z positive; let l be the longitude of the direction YC, measured in the plane YOX from OY, that is, the angle made by YC with OY produced; let λ be the longitude of the direction YB measured in the plane YOB from OY, that is, the angle made by YB with OY produced. Imagine now a sphere described about Y as a center that shall cut the three planes XOY, BOY and BCY in three sides of a right-angled spherical triangle. The hypothenuse of this triangle is λ, the base l, the perpendicular $\frac{1}{2}\pi - \theta$, and the angle opposite to the perpendicular is i; hence we have

$$\cos \lambda = \cos l \sin \theta, \tag{8}$$

$$\cos \theta = \sin i \sin \lambda, \tag{9}$$

$$\cot i = \sin l \tan \theta. \tag{10}$$

Also from the triangles OCY and BCY

$$\tan l = \tan OYC = -\frac{OC}{YC} = -\frac{d}{h \tan \theta}. \tag{11}$$

The angle φ is by definition the angle between the direction OE, and a line in the plane YOB that makes with YB an angle α. Hence we have readily

$$\cos \varphi = \sin i \sin (\lambda \pm \alpha). \tag{12}$$

These equations enable us to compute φ in terms of d, h and ω; for in succession θ may be computed by (3), l by (11), λ by (8), i by (10), and φ by (12).

12. These values of s, p, x and α give by equation (2) the value of $\mathscr{C}$. The suppositions that the planet is at its mean distance, and that $\mathscr{C}_\prime$ is a parabola, are involved in that equation, but they are not necessary to the determination of $\mathscr{C}$ when no such hypotheses are made, and changes in the equation that are not serious would make it applicable without these limitations. The quantities in the several equations may be regarded as having values:—

d positive,
h positive or negative,
α positive and less than $\frac{1}{2}\pi$,
ω, θ, φ and i positive and less than π,
l and λ positive and less than 2π.

13. We may, however, also find directly the value of $\mathscr{C}$ in terms of d, h, and the known functions of ω.

From (12)

$$\cos \varphi \sin \alpha = \sin i \sin \lambda \cos \alpha \sin \alpha \pm \sin i \cos \lambda \sin^2 \alpha.$$

From (7)

$$\cos\alpha \sin\alpha = \frac{AB}{A^2+B^2} \text{ and } \sin^2\alpha = \frac{B^2}{A^2+B^2}.$$

From (10) and (8)

$$\sin i \cos\lambda = \pm \frac{\cos l \sin\theta}{(1+\sin^2 l \tan^2\theta)^{\frac{1}{2}}} = \pm \frac{\cot l \sin\theta}{(\sec^2\theta+\cot^2 l)^{\frac{1}{2}}},$$

hence from (6) and (11)

$$\sin i \cos\lambda = \pm \frac{h \sin^2\theta}{(d^2+h^2\sin^2\theta)^{\frac{1}{2}}} = \pm \frac{h \sin^2\theta}{B}.$$

From these and (9)

$$\cos\varphi \sin\alpha (A^2+B^2) = AB \cos\theta \pm hB \sin^2\theta,$$

and hence from (2)

$$\mathfrak{a} = \frac{s}{4m} \cdot \frac{A^2+B^2}{A\cos\theta \pm h\sin^2\theta} = \frac{s}{4m} \cdot \frac{A^2+d^2+h^2\sin^2\theta}{A\cos\theta \pm h\sin^2\theta}. \tag{13}$$

Since m is the known mass of the planet, and θ, s and A are known functions of ω, equation (13) gives directly the value of $\mathfrak{a}$, the semi-axis major of the new orbit $\mathfrak{C}$ in terms of d, h and ω.

14. For a particular case of approach, equation (13) is convenient for computation. We may, however, now treat d, h and ω as independent variables whose varying values may express all the different possible cases of approach of the comet to the planet so far as change of periodic time of the comet is concerned. The dependence of $\mathfrak{a}$ upon the *three* variables can not be very easily represented graphically in a single plane diagram. But by giving to ω successive values in multiples of 10°, viz, $\omega=10°$, 20°, 30°, etc., to 170°, I have prepared a series of diagrams to exhibit in each case in succession the relation of $\mathfrak{a}$ to the other two variables. The values of θ, s and A for the several values of ω were needed in making the diagrams, and they are given in Table I. Equations (4), (5), and (7) are used in making the table. The disturbing planet is assumed to be Jupiter, so that m was taken equal to 1·1050 and $r=5·2$.

TABLE I.

ω	θ		s	A	ω	θ		s	A
°	°	′			°	°	′		
0	0	0	0·414	·02886	100	131	18	1·868	·00142
10	32	1	0·463	·02309	110	138	9	1·992	·00125
20	55	47	0·585	·01448	120	144	21	2·101	·00112
30	72	22	0·742	·00900	130	150	26	2·195	·00103
40	84	46	0·913	·00591	140	156	26	2·273	·00096
50	94	47	1·087	·00419	150	162	22	2·334	·00091
60	103	27	1·259	·00312	160	168	16	2·379	·00088
70	111	14	1·426	·00244	170	174	8	2·405	·00086
80	118	27	1·584	·00197	180	180	0	2·414	·00085
90	125	16	1·732	·00165					

15. Using these values of θ, s and A we may now represent graphically the dependence of $\mathfrak{a}$ upon the other two variables d and h for each specified value of ω. Let d and h be Cartesian coördinates, then for each point of the coördinate plane there is a value of $\mathfrak{a}$. The ambiguous sign will be fully satisfied by giving positive and negative values to h. For an assumed value of $\mathfrak{a}$ we shall have a curve whose equation is (13), and each point of this curve represents values of d and h for which the total action of the planet upon the comet will be to reduce the energy of the comet a constant amount. This locus will be called an *isergonal* curve.

16. *Faisceau of isergonal ellipses.*—The equation (13) of the isergonal curve may be written

$$4m\mathfrak{a} (A\cos\theta+h\sin^2\theta)=s(A^2+d^2+h^2\sin^2\theta),$$

and this is the equation of an ellipse. As $\mathfrak{a}$ changes its value we may treat it as a parameter and we have a faisceau of similar isergonal ellipses, each ellipse symmetrical with the axis of h. The radical axis of the faisceau $A\cos\theta+h\sin^2\theta=0$, and the imaginary ellipse $A^2+d^2+h^2\sin^2\theta=0$,

are theoretically two members of the faisceau. For points on the radical axis $\varpi = \infty$ and therefore for this locus there is no change in the energy of the comet.

17. *Center and area of the isergonal ellipse.*—The center of the isergonal ellipse is upon the axis of h; making $d=0$, and solving for h we have

$$h = \frac{2m\varpi}{s} \pm \frac{2m\varpi}{s \sin\theta}\left(1 - \left(\cos\theta - \frac{As}{2m\varpi}\right)^2\right)^{\frac{1}{2}} \qquad (14)$$

The first term of the second member of (14) is the ordinate of the center, and the second term is the semi-axis major of the ellipse. The ratio of the axes being 1: $\sin\theta$, and As^2 being $=mr$, the area of the ellipse will be equal to

$$\frac{4\pi m^2\varpi^2}{s^2 \sin\theta}\left(1 - \left(\cos\theta - \frac{r}{2\varpi s}\right)^2\right).$$

18. *Maximum action of the planet.*—For two particular values of ϖ the isergonal ellipses become points. These values of ϖ result if the maximum effect of the planet in increasing and in decreasing the energy of the comet takes place, and they are obtained by making the two values of h equal to each other in (14); that is, by making $\cos\theta - \frac{As}{2m\varpi} = \pm 1$. Since at the same time $h = 2m\varpi/s$, we obtain

$$h = \frac{A}{\cos\theta \pm 1}, \text{ and } \varpi = \frac{As}{2m(\cos\theta \pm 1)}. \qquad (15)$$

Let h' and h'', and ϖ' and ϖ'' be the positive and negative values of h and ϖ in (15) and we may construct the following table of their values. As in Table I, Jupiter is assumed to be the perturbing planet:

TABLE II.

ω	h'	h''	ϖ'	ϖ''	ω	h'	h''	ϖ'	ϖ''
0	·01443	∞	3·14	$-\infty$	100	·00426	−·00085	4·17	−0·83
10	·01250	−·15174	3·04	−36·90	110	·00489	−·00072	5·12	−0·75
20	·00927	−·03307	2·85	−10·15	120	·00598	−·00062	6·60	−0·68
30	·00690	−·01290	2·69	− 5·03	130	·00789	−·00055	9·09	−0·63
40	·00544	−·00654	2·61	− 3·13	140	·01149	−·00050	13·71	−0·60
50	·00457	−·00387	2·61	− 2·21	150	·01934	−·00047	23·70	−0·57
60	·00407	−·00253	2·69	− 1·68	160	·04192	−·00044	52·36	−0·55
70	·00382	−·00179	2·86	− 1·34	170	·16336	−·00043	206·30	−0·54
80	·00377	−·00134	3·14	− 1·11	180	∞	−·00043	∞	−0·54
90	·00390	−·00105	3·55	− 0·95					

19. *Explanation of Table II.*—The meaning of the numbers in this table may be explained by an example. If a comet moving in a parabola passes near to Jupiter, and the directions of the two original motions at nearest points of the orbits make an angle of 10°, then the greatest action of Jupiter (during the whole period of transit) in diminishing the velocity of the comet in its orbit about the sun will take place if the two orbits actually intersect ($d=0$), and if the comet in its unperturbed orbit arrives first at the point of intersection at the instant when Jupiter is distant therefrom ·01250 (the earth's mean distance from the sun being unity). The resulting semi-axis major of the comet's orbit about the sun will be 3·04.

On the other hand, the greatest effect in increasing the velocity of the comet will take place when the two orbits actually intersect, the comet in its unperturbed orbit reaches the point of intersection later than the planet, and when the planet is distant therefrom 0·15174. The semi-transverse axis of the resulting hyperbolic orbit about the sun will be 36·90.

20. *Resulting orbits of maximum perturbation.*—The position of the relative orbit about Jupiter in these cases of maximum perturbation for given values of ω is easily determined. From the equations (7), (6), and (15)

$$\tan\alpha = B/A = h \sin\theta/A = \sin\theta\,(\cos\theta + 1).$$

The positive sign gives $2\alpha = \theta$, and the negative sign gives $2\alpha = \pi + \theta$. But the angle 2α in the first case is the angle of the asymptotes inclosing the branch of the hyperbola described about Jupiter by the comet. Since the two original orbits intersect, the plane of the relative orbit contains the planet's path, so that the comet passes directly in front of the planet and being turned backward leaves Jupiter exactly in the direction of Jupiter's quit.* The place of encounter with Jupiter will be near an apse of the comet's resulting orbit about the sun. The comet leaves the planet with the relative velocity v_1, so that if $s<1$ the motion about the sun in the new orbit will be direct; if $s>1$ the motion in the new orbit will be retrograde. That is, by (4) when $\omega < \frac{1}{3}\pi$ the resulting motion is direct; when $\omega > \frac{1}{3}\pi$ the resulting motion is retrograde.

In the second case the angle 2α, being greater than 180°, stands for the angle between the asymptotes exterior to the orbit. Hence the comet passing behind the planet will be turned forward and will leave the planet in the direction of Jupiter's goal, and have a velocity that will send it permanently out of the solar system.

21. The results of article 20 assume that ω is given. To find for what value of ω the period of the resulting orbit is the shortest possible we may put $As^2 = mr$ and $1 - s^2 = 2s\cos\theta$ in (15) so that

$$a = \frac{r}{1 - s^2 + 2s\cos\theta}.$$

To find the minimum for a place $\frac{da}{ds} = 0$ in this equation. This gives $s = \pm 1$, in which result since s is inherently positive only the positive sign is used. But when $s=1$, $a = \frac{1}{2}r$, $h = mr$ and $\omega = \frac{1}{3}\pi$. *Hence the greatest effect of perturbation of a planet moving in a circular orbit in shortening the periodic time of a comet originally moving in a parabola is obtained if the comet's original orbit actually intersects the planet's orbit at an angle of 45°, and if the comet is due first at the point of intersection at the instant when the planet's distance therefrom is equal to the planet's distance from the sun multiplied by the ratio of the mass of the planet to the mass of the sun.*

Fig. 2; $\omega = 10°$.

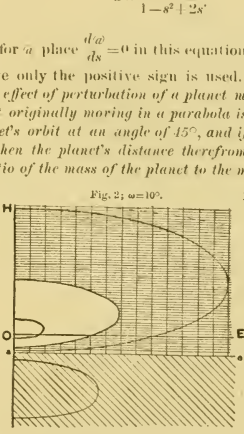


Fig. 3; $\omega = 170°$

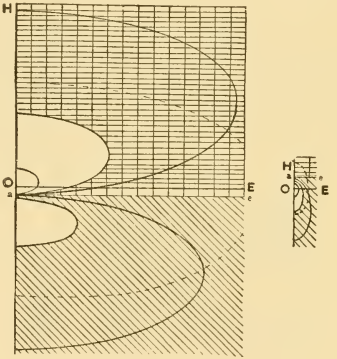
The relative velocity of the comet on leaving the planet's sphere of action would be equal to and directly opposite to the planet's velocity ($s=1$), and the comet would be left entirely at rest to fall to the sun. This case could not happen for planets like the earth where mr is less than the semidiameter of the planet. In the case of the earth mr is less than 300 miles, and actual collision would result. But for Jupiter mr is greater than the distance of the second satellite from the planet. The nearest approach of the comet to the planet would be $mr(\sqrt{2}-1)$, which is more than four times the radius of Jupiter. Hence, this case of maximum diminution of major axis could occur near Jupiter.

22. *Isergonal ellipses for $\omega = 10°$.*—If we make $\omega = 10°$ the vanishing points of the isergonal ellipses will be (Table II) at $d=0$, $h=.01250$, and $d=0$, $h=-.15174$. In Fig. 2 let OE and OH be

* The *goal* and the *quit* of a moving body are those two points on the celestial sphere *towards* which and *from* which the body is moving.

the axes of d and h respectively. The vanishing points will be on the axis OH at distances h' and h'' above and below O. Upon this diagram are shown the halves of four isergonal ellipses. The scales used for d and h are not equal to each other, since the use of the same scale for both coördinates would make the figures of inconvenient shape. In this, and in all the Figs. 2–18, the unit in d is to the unit in h, as 1 to sin ω. But to indicate more clearly this scale, and at the same time to give a kind of shading to a part of the area, there are drawn above the radical axis ae lines parallel to OE and parallel to OH, at intervals of ·01; that is, the sides of each of the small rectangles in the quadrant HOE are ·01, or about 925,000 miles. Only the positive values of d are represented in the figures. The positive vanishing point being 1·250 of these divisions above O, and the negative vanishing point 15.174 below O, we lay off $Oa = \frac{1}{2}(h' + h'') = -6{\cdot}962$ divisions, and draw ae for the radical axis. The smallest positive value of $\mathscr{a}$ is (Table II) 3·04. As $\mathscr{a}$ increases from 3·04 the ellipse increases in size, and the innermost curve represents what it becomes when $\mathscr{a} = 5$. The second curve (separating the blank and shaded areas) corresponds to $\mathscr{a} = 20$. Any parabolic comet passing Jupiter with an original angle of $\alpha = 10°$, and having d and h such as to be represented by a point within the blank area of Fig. 2 will leave the vicinity of the planet in an elliptic orbit whose semiaxis major is less than 20, and whose period, therefore, is less than ninety years.

Fig 4; $\omega = 20°$. Fig 5; $\omega = 160°$.



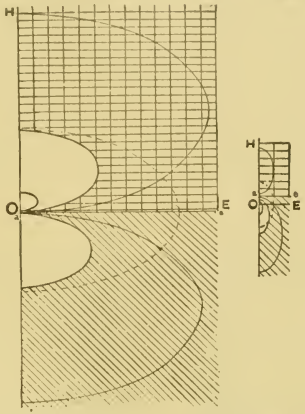
The larger curve that lies above ae in the shaded area is the isergonal ellipse for $\mathscr{a} = 50$. As $\mathscr{a}$ increases the lower part of the curve tends to approach the radical axis ae, with which it coincides when $\mathscr{a} = \infty$. For points in the area below ae (distinguished by the oblique-line shading), the planet increases the velocity of the comets, and the comet would be thrown permanently out of the solar system. The smallest semitransverse axis, the one corresponding to the vanishing ellipse is (Table II) 36·90, and the isergonal curve for $\mathscr{a} = -50$ is drawn in the figure.

23. *Isergonal ellipses for* $\omega = 170°$.—In Fig. 3 are drawn the three ellipses corresponding to the values of $\mathscr{a}$, -5, -20, and -50. The ellipses above ae do not appear, inasmuch as the smallest possible elliptic orbit has a semiaxis major of 206·3 (Table II), and a period of about 3,000 years. The radical axis ae is ·08146 (or over 8 divisions) above OE.

24. Figures 4 and 5 are like diagrams for $\omega = 20°$ and $\omega = 160°$. With altered numbers the explanations of arts. 22 and 23 apply with slight change to these figures. The line ae in Figs. 4 and 5 is nearer to OE than is the same line in Figs. 2 and 3. In Fig. 4 the line for $\mathscr{a} = -20$ appears below ae, while above ae are the three curves for $+5$, $+20$, and $+50$, respectively. In Fig. 5 the ellipse for $\mathscr{a} = 50$ is wanting since the minimum ellipse has a semiaxis major 52·36 (Table II), while below ae the three curves are present.

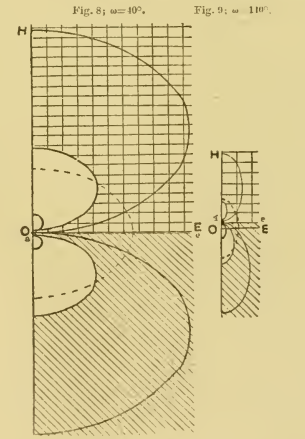
In Figs. 6 and 7 are contrasted in like manner the isergonal curves for the angles $\omega = 30°$, and the supplement of 30°. In Fig. 6 the curve $\bar{a} = -5$ is wanting, and in Fig. 7 the two curves $\bar{a} = 5$, and $\bar{a} = 20$ are both wanting.

Fig. 6; $\omega = 30°$. Fig. 7; $\omega = 150°$.



In like manner are to be explained the Figs. 8–18. The numbers needed for drawing the figures are furnished by equation (13). The curves that in each figure separate the shaded area from

Fig. 8; $\omega = 40°$. Fig. 9; $\omega = 140°$.



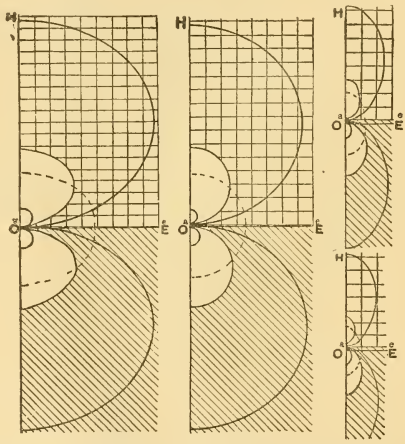
the nonshaded area are the ellipses for $\bar{a} = 20$, and $\bar{a} = -20$. The shading is introduced in order to compare more readily the corresponding curves in the figures.

25. The dotted curve in the several figures represents those values of d and h for which the total change of direction in the relative orbit is 10°; that is, $\alpha=85°$. It is that curve whose equation is A tan 85°=B, or $d^2+h^2 \sin^2 i=A^2 \tan^2 85°$. It is therefore an ellipse whose center is the origin of coördinates, and it is similar in each figure to the isergonal ellipses.

26. *Hypotheses about the parabolic cometary orbits.*—It will be convenient to make two assumptions about the distribution of the parabolic comets, and the distribution of the goals of their motions. There seems to be no very well marked relation between the ecliptic, or to speak more strictly, the invariable plane of the solar system, and the known parabolic cometary orbits. The following two assumptions do not seem likely, therefore, to introduce any very serious error into our reasonings.

If about the sun as a center a sphere $\mathfrak{S}$ be described with an arbitrary radius r, it will be *assumed* that near the surface of $\mathfrak{S}$, space is filled equably with comets. We may express this by supposing that in each cubic unit of space near $\mathfrak{S}$, there are at each and every instant n comets. As the orbits are all assumed to be parabolic, the n comets have a common velocity v.

Fig. 10; $\omega=50°$. Fig. 12; $\omega=60°$. Fig. 13; $\omega=120°$. Fig. 11; $\omega=130°$.



It will be furthermore *assumed* that the directions of the comets in each cubic unit of space near $\mathfrak{S}$ are at random, that is, that the quits and goals of the comet's motions relative to the sun are distributed equably over the surface of the celestial sphere.

27. *Number of comets entering* $\mathfrak{S}$.—If about a normal to $\mathfrak{S}$ as an axis there be described two cones cutting the celestial sphere in two small circles distant from the point where the normal meets the celestial sphere ψ and $\psi+d\psi$, then of the n comets there will be $\frac{1}{2}n\sin\psi d\psi$ comets whose quits are between the two circles. Each of these comets will move perpendicularly to the spherical surface $\mathfrak{S}$ with the velocity $v\cos\psi$. Hence in a unit of times $\frac{1}{2}nv\cos\psi\sin\psi d\psi$ comets will cross a unit of the surface $\mathfrak{S}$ going toward the sun. The total entering the sphere in the unit of time will be this number multiplied by the number of units in the surface of $\mathfrak{S}$, or

$$2\pi r^2 \int_0^{\frac{1}{2}\pi} nv\cos\psi\sin\psi d\psi=\pi nvr^2.$$

28. *Distribution of parabolic comets as to perihelion distance.*—This supposition of equable distribution of the goals of comets as they cross the spherical surface $\mathfrak{S}$ involves also a law of distribution of comets as to perihelion distance. The number of comets that enter the sphere in a given time whose motions make with the normal angles between ψ and $\psi+d\psi$ is proportional to $\sin\psi\cos\psi d\psi$. If N be the number of comets that enter $\mathfrak{S}$ in a given period of time with an angle with the normal less than ψ, we may write $dN=k\sin\psi\cos\psi d\psi$, where k is some constant. But if q is the perihelion distance of a comet which at the distance r from the sun moves at an angle with the radius equal to ψ, then $q=r\sin^2\psi$, and $dq=2r\sin\psi\cos\psi d\psi$. But comets that enter $\mathfrak{S}$ with angles to the normal between ψ and $\psi+d\psi$, have perihelion distances between q and $q+dq$. Hence N may also represent the number of comets that in the given period of time pass their perihelia, and whose perihelion distances are less than q. Therefore $\frac{dN}{dq}$ is a constant, and we conclude that if comets be grouped according to their perihelion distances the number of comets whose perihelion distances are less than q is proportional to q.

Fig. 14; $\omega=70°$.

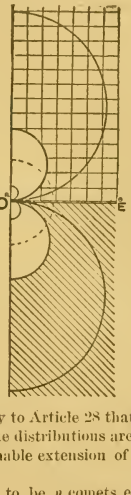
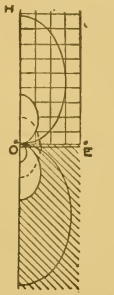


Fig. 15; $\omega=110°$.



29. It follows as a corollary to Article 28 that if the two assumptions of Article 26 be made for the spherical surface $\mathfrak{S}$, the like distributions are true for every smaller concentric spherical surface. It would be but a reasonable extension of the assumptions to make them apply to larger spheres, if finite.

30. If there are assumed to be n comets equably distributed in each unit of the space near and through which a planet is moving, and if these comets are all assumed to be moving in parabolas about the sun with the velocity v, having also their directions of motion equably distributed, then the number that are moving from quits lying within an element $d\mathrm{S}$ of the surface of the celestial sphere will be $\frac{nd\mathrm{S}}{4\pi}$. Let v_0 be the common velocity of these comets relative to the planet. Then suppose that a spherical surface S′ is described with a radius r' about the planet as center; r' being small relative to the sun's distance, yet not so small as to forbid the omission of the planet's perturbing action so long as the comet is without the surface S′. In each unit of time out of these comets directed from the element $d\mathrm{S}$ of the celestial sphere there would pass nearer than r' to the planet $n\frac{d\mathrm{S}}{4\pi}\cdot\pi r'^2 v_0=\frac{1}{4}nv_0r'^2\,d\mathrm{S}$ comets if unperturbed. Evidently an equal number cross the surface S′ entering the sphere in each unit of time.

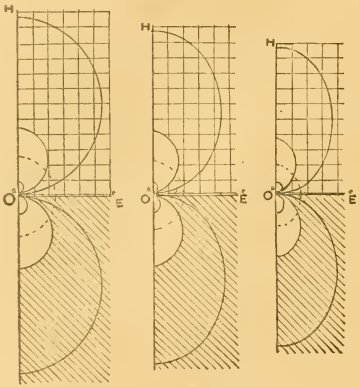
If now ω be the angle which the comet's unperturbed motion is making with the planet's motion, and if v_1 or its equal, $v'\sqrt{2}$, be the planet's velocity in its orbit about the sun, then $v_0^2 = \frac{1}{2}v^2[3-2\sqrt{2}\cos\omega]$. The element $d\mathrm{S}$ may be taken to be the elemental zone between the two small circles, whose common pole is the planet's quit, and whose distances from the planet's quit are ω and $\omega+d\omega$. Then $d\mathrm{S}=2\pi\sin\omega\, d\omega$. The number of comets entering S′ in a unit of time with quits within that elemental zone will be

$$\tfrac{1}{4}\pi v_0 r'^2 \times 2\pi\sin\omega\, d\omega = \frac{\pi\pi v r'^2}{2\sqrt{2}}(3-2\sqrt{2}\cos\omega)^{\frac{1}{2}}\sin\omega\, d\omega.$$

The integral of this,

$$\frac{\pi\pi v r'^2}{2\sqrt{2}}\int_0^{\pi}(3-2\sqrt{2}\cos\omega)^{\frac{1}{2}}\sin\omega\, d\omega = \tfrac{7}{6}\pi\pi v r'^2,$$

Fig. 16; $\omega=80°$. Fig. 17; $\omega=90°$. Fig. 18; $\omega=100°$.



expresses the total number of comets that, under the hypotheses that have been made, would, in a unit of time, enter the sphere S′.

31. If we compare the two expressions obtained in articles 27 and 30 we find that the number of comets which, in a given period of time, come nearer to the sun than r is to the number that (unperturbed) come nearer to the planet than r' as $6r^2$ is to $7r'^2$. The factor $\frac{7}{6}$ expresses the increase of numbers caused by the planet's motion in its circular orbit. The value of r', as has been said, must not be too small, nor yet must it be very large.

32. In order to determine the number N of comets which, in a unit of time will have their periodic times reduced below a given period, we may make use of the isergonal curves represented in Figs. 2–18. Although the diagrams were not constructed to exhibit the motions of the bodies, yet they may be utilized for that purpose. Let OH be the tangent to the planet's orbit, O the place of the planet considered at rest, and let the plane HOE contain the shortest line d between the two orbits. This d will be the abscissa of the point at which the comet's unperturbed orbit will cut the plane. The ordinate of the same point, produced if necessary, will be the projection of the comet's path upon the plane HOE, and the comet's path makes with the plane the angle θ. The velocity of the comet perpendicular to the plane will be $v_0\sin\theta$. By reason of the hypothesis that the comets are equably distributed, the points of intersection with the plane HOE will be equably distributed over the plane. Hence the number of comets whose quits are in the element $d\mathrm{S}$ of the celestial sphere and that will pass the planet in a unit of time in such a way as to have

their periodic times reduced below a given period will be equal to the area inclosed in the corresponding isergonal curve multiplied by the velocity perpendicular to the plane $r_0 \sin\theta$, and by the factor $\frac{ndS}{1\pi}$. If a is the seminajor axis of the orbit for the limiting periodic time, the area of the corresponding isergonal curve will be (article 17),

$$\frac{\pi}{\sin\theta}\left(\frac{4m^2a^2}{s^2}-\left(\frac{2ma\cos\theta}{s}-\frac{mr}{s^2}\right)^2\right).$$

For dS we may, as before, take $2\pi \sin\omega\, d\omega$, and we shall then have

$$N=\frac{\pi n}{2}\int r_0\sin\omega\left[\frac{4m^2a^2}{s^2}-\left(\frac{2ma\cos\theta}{s}-\frac{mr}{s^2}\right)^2\right]d\omega.$$

The integration must extend through the positive values of the quantity in square brackets beginning at $\omega=0$. [In case $\omega=0$ gives a negative value for the quantity in square brackets we must integrate between the two values of ω corresponding to the zero value of the bracketed quantity.] We may make s the independent variable by the equations $sds=\sqrt{2}\sin\omega d\omega$, $r_0\sqrt{2}=sv$, and $2s\cos\theta=1-s^2$.

These give:

$$N=\tfrac{1}{4}\pi n m^2 v\int\left[\tfrac{4}{s}a^2-\left(\frac{a}{s}-r-\frac{a\,s^2}{s}\right)^2\right]ds.$$

33. If, now, we require the number of comets which, in each unit of time, shall pass the planet in such way as that they shall have, after the passage, respectively, less than one-half, once, three-halves, and twice the planet's period of revolution

we may place $a=rT^{\frac{2}{3}}$, and make T equal, successively, to $\frac{1}{2}$, 1, $\frac{3}{2}$, and 2, and compute in each case the value of N as given in the last article. The results are found to be $\pi n m^2 r^2 v$ multiplied severally by the coefficients 0·139, 0·925, 1·875, and 2·943.

34. By comparing the results of articles 27 and 33, and making the assumptions of article 26, we have the proposition that *the number of comets which, in a given period of time, pass their perihelia nearer to the sun than a given planet, is to the number of comets whose periodic times are reduced by the perturbing action of the planet so as to be less severally than one-half, once, three halves, and twice, the periodic time of the planet, as unity is to the square of the mass of the planet multiplied severally by* 0·139, 0·925, 1·876, *and* 2·943.

35. If Jupiter is the planet, $m=\frac{1}{1047}$, and we may express these ratios as

1,000,000,000 : 126 : 839 : 1701 : 2670.

That is, assuming the hypotheses of article 26, and regarding the planet as without dimension so as to intercept any comets, *if in a given period of time a thousand million comets come in parabolic orbits nearer to the sun than Jupiter, 126 of them will have their orbits changed into ellipses with periodic times less than one-half that of Jupiter; 839 of them will have their orbits changed into ellipses with periodic times less than that of Jupiter; 1,701 of them will have their orbits changed into ellipses with periodic times less than once and a half times that of Jupiter; and 2,670 of them will have their orbits changed into ellipses with periodic times less than twice that of Jupiter.*

36. Another and perhaps a more important inquiry is this. What effect have the perturbations of the planet in bringing or not bringing the comets to move in the same direction that the planet is moving after the comets have by perturbation had their periodic times largely reduced? For simplicity and as a special example I shall consider the action of Jupiter only, and also only his action upon those comets whose periodic times are reduced to be less than Jupiter's period, the original orbits of the comets being parabolic. In other words, how many of the 839 comets which are reduced (article 35) to have periodic times less than Jupiter's period will, after perturbation, have goals distant less than 15°, 30°, 45°, etc., severally from Jupiter's goal?

37. Let BA, Fig. 19, be drawn to represent v_1 and CA to represent $v_2\sqrt{2}$. With A as a center and AB and AC as radii describe the semicircumferences BLO and CHG. Let the angle BAH be made equal to ω and BH be drawn; then HA will represent the comet's velocity about the sun, BA the planet's velocity about the sun, and therefore HB the comet's velocity v_0 in its orbit about the planet before perturbation. About B as center describe the semicircumference KHT. Since

the relative velocity after as well as before perturbation is equal to HB, therefore the velocity of the comet about the sun after perturbation will evidently be represented by a line drawn from some point in the semicircumference KHT to A. If the velocity is increased, the new velocity will be represented by a line to A from some point in the arc KH; if diminished, by a line to A from some point in the arc HT. If the new velocity is less than the planet's velocity, and so the new cometic period less than the planet's period, the new velocity will be represented by a line to A from some point in the arc ET. If in a diagram constructed for $\omega = BAH$ the isergonal curve be drawn for $@ = r$, those comets for which d and h represent points within that isergonal curve will, after perturbation, have velocities represented by lines drawn from points in ET to A, while comets for which d and h represent points outside that isergonal curve will, after perturbation, have directions of motion represented by lines drawn to A from points in EHK. The number of comets having motions represented by lines to A from points in ET will be proportional to the area of the isergonal curve $@ = r$. Let the angle BAS represent a limiting value ω'' of distance of quits of comets from Jupiter's quit after perturbation. The comets which are thus limited and at the same time have $@ < r$ will be moving in lines directed to A from points in the area bounded by the straight lines SA and AF, and the arcs FD and DS. Let ω receive an increment $d\omega = Hh$ and let a new semicircumference be drawn with Bh as radius. To the elemental arc Hh will cor-

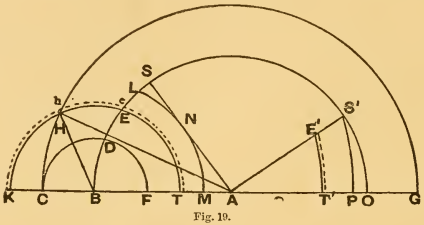


Fig. 19.

respond the elemental area along the semicircumference KET. If ET lies wholly in SAFD the number of comets that pass the planet in a unit of time having initial angles of direction with Jupiter's motion between ω and $\omega + d\omega$ will be equal to the area of the isergonal curve for $@ = r$ multiplied by the elemental number $\frac{1}{2}n \sin \omega d\omega$, and by the relative velocity $v_0 \sin \theta$ of the comet perpendicular to the isergonal area. If the area of the isergonal curve be represented by $\Phi/s^2 \sin \theta$, then this product will be

$$\frac{\Phi}{s^2 \sin \theta} \cdot v_0 \sin \theta \cdot \frac{n \sin \omega d\omega}{2} = \frac{nv}{4} \Phi ds$$

since $\sqrt{2} v_0 = sr$, and $\sqrt{2} \sin \omega d\omega = s ds$.

38. This expresses the elemental number of comets corresponding to the elemental area Te. The integral of this expression, that is, $\frac{1}{4} nrf \Phi ds$, so taken as to cover the area AFDS will give the number of comets which in a unit of time will pass the planet in such a way as to have $@ < r$ and $\omega' <$ BAS. When the elemental area does not extend from the arc DS to the line BA, the area of another appropriate isergonal curve is to be used in determining Φ.

By article 17 we have

$$\Phi = \pi m^2 \left[4@^2 - \left(\frac{@ - r - @s^2}{s} \right)^2 \right].$$

For the elemental areas of the surface AFDS which end on the arc DS we make $@ = r$, and let Φ_0 be the resulting value of Φ; then $\Phi_0 = \pi m^2 r^2 (4 - s^2)$.

For elemental areas that end on the radius AS the values of $@$ on that line are functions of s. To compute them let v' be the comet's velocity in its orbit about the sun, and hence equal to the distance of the point on AS from A; then by the triangle of velocities

$$v_1^2 + v'^2 - 2v'v_1 \cos \omega'' = v_0^2 = s^2 v_1^2.$$

Again by the laws of gravitation,

$$v'^2=\left(2-\frac{r}{\varpi}\right)v_r^2.$$

Hence

$$s^2=3-\frac{r}{\varpi}-2\sqrt{2-\frac{r}{\varpi}}\cos\omega'',$$

or

$$\frac{\varpi}{r}=\frac{3-s^2-2\cos^2\omega''+2\cos\omega''(s^2-\sin^2\omega'')^{\frac{1}{2}}}{9-8\cos^2\omega''-6s^2+s^4}.$$

Let Φ' and Φ'' be the two values of Φ obtained by substituting in Φ these values of ϖ, Φ'' representing the value for the point nearer to A.

39. If $\omega''=90^\circ$, and therefore $\cos\omega''=0$, we have along the limiting line, the two values of ϖ equal, hence

$$\frac{\varpi}{r}=\frac{1}{3-s^2},\text{ and }\Phi'=\frac{s^2-1}{s^2(3-s^2)^2},$$

so that the number of comets having quits less than 90° from Jupiter's quit and $\varpi<r$ is

$$\frac{nr}{4}\int_{\sqrt2-1}^{\sqrt2}\Phi_0 ds-\frac{nr}{4}\int_1^{\sqrt2}\Phi' ds=\frac{\pi n r m^2 r^2}{4}\left[\int_{\sqrt2\ 1}^{\sqrt2}(4-s^2)ds-4\int_1^{\sqrt2}\frac{(s^2-1)\,ds}{s^2(3-s^2)}\right]=\frac{\pi n r m^2 r^2}{12}(7+\sqrt2)$$

$$=\cdot7012\ \pi n r m^2 r^2.$$

Since the whole number of such comets is (Art. 33) equal to $\cdot925\ \pi n r m^2 r^2$, the number of comets the distance of whose quits from Jupiter's quit is between 90° and 180° is $\cdot224\ \pi n r m^2 r^2$. The number of the comets for which $\varpi<r$ that have inclinations to the ecliptic less than 90° is to the number that have inclinations greater than 90° as 701 is to 224. *Of the 839 comets spoken of in article 36, 203 will after perturbation have retrograde motions, and 636 will have direct motions.*

40. If ω'' is less than 90° the expression to be integrated in order to cover the area SAFD will be

$$\int_{\sqrt2-1}^{\sin\omega''}\Phi_0 ds+\int_{\sin\omega''}^{2\sin\frac{1}{2}\omega''}(\Phi_0-\Phi')\,ds+\int_{\sin\omega''}^{1}\Phi''\,ds.$$

If ω'' is greater than 90° the corresponding expression becomes

$$\int_{\sqrt2\ 1}^{2\sin\omega''}\Phi_0 ds-\int_1^{2\sin\frac{1}{2}\omega''}\Phi''\,ds.$$

As the value of ϖ introduces into Φ' and Φ'' only one radical in s, and that a radical of the second degree, these integrations are possible. Finite summation is, however, more convenient. Computing the values for each interval of 15°, we construct the following table. The first column indicates the interval in values of ω''; the second column gives that coefficient of $\frac{1}{4}\pi n r m^2 r^2$ that must be used to obtain the number of comets, which in a unit of time will pass perihelion nearer than Jupiter's distance to the sun, shall also have their periodic times reduced to be less than Jupiter's period, and shall also leave Jupiter's vicinity so that the distance between the quits of the two bodies is between the two values in column 1; the third column indicates the distribution of the 839 comets of article 36 through the twelve zones.

TABLE III.

Limiting values of ω	Coefficient of $\frac{1}{4}\pi n r m^2 r^2$.	No. out of 839 comets.
From 0 to 15	26	6
From 15 to 30	401	91
From 30 to 45	751	170
From 45 to 60	670	152
From 60 to 75	548	121
From 75 to 90	443	101
From 90 to 105	296	67
From 105 to 120	235	53
From 120 to 135	162	37
From 135 to 150	99	23
From 150 to 165	50	11
From 165 to 180	16	4

We see also from the last column of this table that of the 839 comets under consideration 267 have quits less than 45° from Jupiter's quit, while only 38 of them have quits within 45° of Jupiter's goal.

41. Table III gives the distribution of the comet quits relative to Jupiter's quit. It may also be used to determine how many of the comets whose orbits are thus changed shall have an inclination to the plane of Jupiter's orbit less than a given angle.

Let the angle be 30°. Let Q be Jupiter's quit on the celestial sphere, Q′ the comet's quit, and S the sun's position as seen from Jupiter. Then in the triangle QQ′S put ω'' for QQ′ the distance of the quits. The side QS = 90°, and the QSQ′ will be the inclination of the orbits. Represent this angle by i and the angle Q′QS by η. Then $\sin \eta = \cot \omega'' \cot i$.

Let two small circles be drawn about Q at distances ω'' and $\omega'' + d\omega''$ then if $d\omega''$ be made 15° the numbers in the second or third columns of Table III indicate how many quits are in the several zones of 15° on the celestial sphere. These may be distributed at smaller intervals than 15° by known processes. All the quits that lie in the lune between two semicircles drawn through S so as to make angles of 30° with QS will evidently have orbits inclined less than 30° to Jupiter's orbit. From $\omega'' = 0$ to $\omega'' = 30°$ all the quits are included in the lune. From $\omega'' = 30°$ to $\omega'' = 90°$ we compute η from the equation $\sin \eta = \cot \omega'' \cot 30°$; then the portion of the quits in any elemental zone that fall in the lune is to the whole number of quits in that elemental zone as this value of η is to 90°. These may be summed by finite summation, and the result is that among the 839 comets 257 would move in orbits inclined less than 30° to the orbit of Jupiter.

42. If a like summation be made for the equal lune that contains Jupiter's goal we find 51 to be the number out of the 839 comets which move in orbits inclined more than 150° to Jupiter's orbit; that is, *somewhat more than five times as many of these comets move in direct orbits inclined less than 30° to Jupiter's orbit as move in retrograde orbits inclined less than 30° to Jupiter's orbit.*

43. The comet has been thus far considered as approaching Jupiter while moving in a parabolic orbit about the sun. If the comet, however, is moving in any other orbit, and it passes near to the planet, the result of the planet's perturbing action will in general be quite similar to the result when the orbit is parabolic, the other circumstances of the approach being assumed to be alike in the two cases.

44. These are perturbations during one transit past the planet. But the comet, unless the orbit is further changed by another planet, must return at each revolution to the place where it encountered Jupiter. At some time Jupiter will be nigh that place nearly at the same time as the comet, and the comet will suffer a new and perhaps a large perturbation. Its period will again be changed, being shortened or lengthened according as the comet passes before or behind the planet. This process will be repeated again and again, since, after any number of encounters, the new orbit of the comet will still pass near to the orbit of the planet.

This repeated action makes it possible to have an orbit shortened in period by several passages near to Jupiter instead of its being done at one passage. A much larger proportion of comets than 839 out of 1,000,000,000 might therefore have their periodic times reduced below the period of Jupiter.

45. If the comet's orbit is largely inclined to the ecliptic and hence its motion makes a large angle with that of Jupiter the diagrams Figs. 10–18 show that there is nearly an even chance that the velocity will be increased or diminished. A considerable fractional part of the whole number of such comets will at each passage be thrown out of the solar system altogether, or thrown into such long orbits that they will return only at very great intervals of time. This class of comets can not be therefore regarded as permanent members of the family of short period comets, except such of them as happen to come so near to other planets as to have their orbits changed in such wise that they do not have thereafter the near approach to Jupiter's orbit. But when an orbit is greatly inclined to the plane of the solar system the comet passes through the plane in general at a considerable angle and the chance of coming close to another planet is relatively small.

46. On the other hand all the comets which after perturbation are moving in orbits somewhat but not greatly inclined to the ecliptic are liable to meet, in fact are sooner or later almost certain to meet other planets in such a way as to suffer perturbations that will prevent future close

encounters with Jupiter. After such changes those comets must be regarded as tolerably permanent members of the solar system.

47. Comets that have motions not greatly inclined to Jupiter's motion, are, as Figs. 2 and 4 show, more likely in subsequent passages near to Jupiter to have their periodic times shortened than lengthened. On the contrary those passing in nearly opposite direction to Jupiter's motion will as Figs. 3, 5, and 7 show, be much more likely to have their periods lengthened than shortened.

All these causes combine and work together to the one end that those comets which are changed by the perturbing action of Jupiter, or other planets, from parabolic orbits of every possible inclination to the ecliptic into short period ellipses and become permanent members of the solar system, will as a rule (but with exceptions) move in orbits of moderate inclination to the ecliptic, and with direct motions.

We know as a fact that most short period comets do move in orbits having small inclinations and direct motions, while long period and parabolic comets move at all possible inclinations to the ecliptic. If the short period comets have been changed by Jupiter and other planets from parabolic orbits, the preceding investigation shows why their orbits have now small inclinations to the ecliptic, and the comets themselves have direct motions.

NATIONAL ACADEMY OF SCIENCES.

VOL. VI.

SECOND MEMOIR.

ATMOSPHERIC ELECTRICITY.

A STUDY ON THE RELATION OF ATMOSPHERIC ELECTRICITY, MAGNETIC STORMS, AND WEATHER ELEMENTS TO A CASE OF TRAUMATIC NEURALGIA.

By Robert Catlin, U. S. A.

I have asked Capt. Catlin to present this paper because of its unique importance. When years ago at my desire he began to observe his own case with scientific care, no essay on a like subject existed. Except the papers in which he continued his self-study there are even now no companion essays to put alongside of his record. On a former occasion I read to the academy a report of his case, and to-day need only remind it that Capt. Catlin lost a leg in 1864, that neuralgia followed and was felt chiefly as in the lost foot. The neuralgia was very definite in its onsets and endings. The observer, a quiet student of science, was free from risks of suggestive emotions; also he had time at his disposal. The Weather Bureau gave all else that we needed, and the final results as now summed up for publication in your proceedings are certainly most valuable.

S. Weir Mitchell, M. D.

ATMOSPHERIC ELECTRICITY.

In the ordinary or local manifestation of atmospheric electricity as in thunderstorms, there seems to be in the case of neuralgia under consideration no relationship; the nerves remain unaffected. Nor is it clear that the undetermined fluctuating values of atmospheric electricity attending cyclones have an influence. It is not, however, unusual to witness after severe thunderstorms accompanying cyclone movements the phenomenon of so-called "heat lightning" as an apparent product of the storm, and this it is believed may terminate in the true auroral display, or a magnetic storm, and becomes in this form, if sufficiently intense, as we have attempted to show elsewhere, a contributor to pain condition. Excepting the record of Dr. Wislizenus, it is believed that no mean annual or diurnal values have yet been determined in this country. In presenting the continuous curves (Figs. I, II) from the Baltimore record made for the Weather Bureau, 1885–'86, the law of *annual* fluctuation so far as we are able to discover by comparison of the winter curves Fig. I with the summer of Fig. II, gives a *higher mean positive value for winter than for summer.*

In the *diurnal* fluctuations, by a reference to Figs. I, II, we can readily detect a composite mean the curve of which would present unmistakably one principal maximum for the day and a principal minimum for the night. The record seems too limited to disclose any subordinate maximum or minimum which probably do exist. *The diurnal electrification seems to have a common ratio with temperature, and the annual an inverse.*

Each composite in Figs. I, II, is made up of sixty curves. Fig. I for the six winter months, October to March, inclusive, and the first ten days (record permitting) of each month selected. Fig.

II is similarly constructed for the six summer months. Figs. III and IV each represents the electrical composite of sixty days also, covered by the two years used in Figs. I and II upon which the neuralgia prevailed. Comparison of these with Figs. I and II shows a lower mean value of positive electricity and a decided increase in the negative product. Fig. IV has a larger percentage of summer neuralgia in it than has Fig. III.

Comparison, then, of one hundred and twenty curves of electricity taken on neuralgic periods with one hundred and twenty curves taken as already stated shows that *pain seeks identity with low positive and negative curves and with fluctuating values of great amplitude.*

MAGNETIC STORMS ACCOMPANIED BY AURORA.

In our original paper (p. 23, April, 1877,)* attention was first drawn to the association of neuralgia and aurora during the decennial sun spot or auroral period of 1868–1873. No record was made of neuralgia at the time of this supposed relationship, and it became necessary to await the next recurring period, which reached its maximum in 1882 and 1883. We repeated this belief of relationship in our next paper (p. 18, June, 1883),† and our record then brought us to the middle of the auroral period. Having passed through that period, and having the records nearly complete of the magnetic and auroral displays, it is now possible to contribute additional evidence to what originally seemed to be a relation or a coincidence.

To cover the period of greatest auroral activity we have selected seven of the greatest electrical storms from April, 1882, to November, 1883, and one isolated storm of March, 1885. In describing these eight storms we have used the monthly weather review, Prof. McAdie's professional note of the Signal Bureau, and the monthly reports of the Toronto Observatory and our own notes made at the time. Referring to Fig. V the last column is the auroral record—the stars indicate the visible display and the dots the suspected. Taking an exact copy of the contemporaneous curve of pain and weather made at time and from day to day, and placing in position according to date of auroras, and there is at once an obvious relation, and each aurora throws some coloring on the pain and storm condition. But the greatest surprise of all was, having selected the magnetic storms and placing the other curves in position—to find that from April, 1882, to March, 1885, there were but seven attacks of pain of the greatest intensity, such as have already been discussed in previous papers—and that of these seven, four of the greatest of them should turn up in this diagram of a record of only eight magnetic storms.

Corresponding to the attack of November, 1882, we have probably the greatest magnetic storm of which any record is made. This and its relationship to the pain attack was described in paper of June, 1883 (pp. 17, 18). As stated then, no cyclone storm was present.

Passing to the next, of September, 1883, we find the pain curve from the 10th to the 14th was probably under the influence of the great hurricane storm No. IV, as traced in the monthly review of this date, with falling barometer over nearly the whole country. The auroral display did not occur till the 15th. According to the Toronto report covering this time it seems while there was some declination trouble on the 11th and 12th, it was not until the evening of the 15th, accompanied by the aurora, that the heaviest magnetic storm since the previous November began and lasted all night and was renewed with considerable intensity the next night. We find pain of the usual intensity corresponding to this display. A cyclone storm followed on the 16th and 17th.

Taking up the third (November, 1883,) long attack, as given in the diagram, we find a record of four days' pain out of the week—18th to 24th. The magnetic storm, as given by the Toronto record, was active from the 19th to 22d, inclusive. Three cyclone storms also passed during same period.

The magnetic storm of March, 1885, was active from the 12th to the 16th, and especially so during the brilliant aurora of the 15th, which was also reported as disturbing the magnetograph at Kew (England) all day. Three cyclone storms moved within neuralgic range from the 12th to the 16th.

The aurora of the night of August 4, 1882, placed as on diagram, extended clear across the continent and as far south as Florida. A cyclone depression on the 4th was within neuralgic range.

* American Journal Medical Sciences. † Vol. VI Transactions of College of Physicians, Philadelphia.

The aurora of the night of April 16 and 17 was one of the most brilliant of the year. At the same time in England "a magnetic storm of unusual intensity raged from midnight of the 16th to midnight of the 17th." There were no cyclones within neuralgic distance during this time.

On the 2d of October occurred an important one, and was visible from the lake region across the Atlantic to England, when a magnetic storm was registered at the Royal Observatory. A cyclone passed at extreme limit of neuralgic distance on the 2d and 3d.

Corresponding to the neuralgic attack of December 15 and 16 there was an extensive and brilliant aurora. There was no cyclone within neuralgic distance during this attack. There are other magnetic storms, with accompanying aurora, which further illustrate the relationship here considered. Such storms are those of October 2, 1882, February 24, 1883, April 3, 1883, July 29, 1883, November 2, 1883, and others of less note.

COMPARISON OF WEATHER ELEMENTS WITH THE PAIN CURVE.

All that we have written in the two former studies stands substantially confirmed by the extension of the record seven years more.

In Fig. C, paper of 1883, we presented a relationship between the pain, pressure, and temperature curves. A continuation of the record for the additional time maintains the relationship there expressed, perhaps not so accurately, for the pain has during this latter period decreased at the annual rate of fifty-eight hours instead of forty hours, as stated in last paper for a previous period; and also for four years of this additional period the pain curve was constructed farther away from the storm track, which would have the effect of making relationship less marked.

The barometric and other curves as presented in Fig. D (paper of 1883) stand unaffected, but it is proposed to make a closer monthly comparison of the various meteorological elements with the pain curve extending through many years. For this purpose we have constructed the curves as shown in Fig. E. From this we are enabled to present Table A, in which the column with + sign shows number of times the weather curves were found parallel with the pain curve, and the — sign indicates the number of times they were divergent.

It will be seen that the pressure curve during the one hundred and sixty-eight months, or fourteen years, has 56 per cent of the time parallel with the pain and 44 per cent not coinciding with it. The mean hourly wind velocity for eleven years stands 51 per cent parallel to 49 per cent not so, which indicates that force of wind may be eliminated as a factor of pain. In the next column the "number of days of rain" for same time shows a stronger parallelism than the pressure; so, also, does relative humidity, depth of rain and ozone. We add the ozone curve with some hesitation on account of the well-known difficulties in making a correct record of it. This, as most of these are, is from the Central Park Observatory under Prof. Daniel Draper. The pain curve, for most part, was constructed more than 20 miles away from place of these records. The temperature curve, the hours-of-sunshine curve, and, to some extent, the elastic-force-of-aqueous-vapor curve, which bears nearly an inverse relation to relative humidity, are large in their negative values and operate to diminish pain, while all the others, excepting wind, but including *number* of storms, increase amount of pain.

The storm curve, which bears the same relation to pain as the pressure curve, is constructed for the most part on Lieut. Finley's tables, and partly from annual and monthly reports of the Signal Bureau.

To demonstrate more closely the relationship between pain and the *number* of storms, we have taken twelve months scattered through the whole period from 1875 to 1885, inclusive, which gave the highest pain readings. The result is as presented in Table B, in which the + sign gives the value *above* the mean for the month, and the — sign the value *below* mean for same. The + and — values of pressure are almost equal for the twelve months, but for same period there were five and a half days of rain in excess of mean and 4 inches of excess of rain, a slight excess of relative humidity, and, as we should expect, a negative value in elastic force of vapor. A marked feature, however, of this table is the low temperature, being a deficiency for the whole twelve months of over 14° (—14.20), or an average deficiency of over 1° a month. Another very marked

feature is in the storm column, which gives an excess of thirty-one storms, or an average of nearly two and a half per month above the mean, and by analyzing we find ten months above the mean and not one below. Thus it is manifest, by generalizing on the extremes of maximum months of pain readings, that we add great potency to the law of relationship between pain and storm.

By going to the other extreme and taking a similar number of minimum pain readings, Table C, we find the values reversed—a slight deficiency in relative humidity, with large positive value of force of vapor. The number of days of rain fall very short of the average, being twenty-six days for the thirteen months below the mean. The depth of rain falls short nearly 17 inches, while the temperature was over 10° above the mean, or nearly 1° higher per month than the average. The number of storms is almost as far below the mean as they were found to be above in Table B.

It will be seen in Table C that there are three small + values in the column under "number of storms;" but if we turn to the Signal Service chart for June, 1878, we read, "Four of the storms too indefinite to be computed," which if canceled would give us a −3 instead of +1, and by a similar reference to May, 1880, chart we find three belong to the Pacific, and finally for the other apparent exception, the August, 1884, chart places most of the "lows" at an unusually high latitude, "above latitude 48°," and most of them beyond or at extreme neuralgic distance. From these two tables (B and C) of extremes we, then, are enabled to state the following law: *That maximum pain bears a direct proportion to storm frequency and an inverse proportion to temperature and elastic force of vapor, and minimum pain bears an inverse proportion to storm frequency and a direct to temperature and elastic force of vapor; while depth of rain, etc., go along with number of storms and maximum pain.*

In this connection it is evident that meteorological charts of *relative storm frequency* would be of service to the neuralgic subject in selecting a habitation.

"SPELLS" OF WEATHER.

In the annual changes of weather, from January to July and from July to January, and, indeed, in regard to movement of storms in general, the law of mean change is uniform, but if we differentiate the mean we can in any one year detect a departure from the law of uniformity, by an injection here and there of an abnormal break which may last one to three weeks. These breaks are more likely to occur in late fall or early spring, but may happen any time, and these are known as "spells," and may be associated with the cold or warm "types" of weather, or, indeed, with any unusual condition probably brought about by the changing shapes and relative position of the great anticyclone areas. Early in the history of this case the pain, both in amount and intensity, became associated with these "spells," the intenser forms of pain occurring at beginning of the "spells." So also when a uniform condition of weather prevails, as in period of drought, a diminution of pain obtains.

MONTHLY RATIOS OF PAIN.

In determining the relative ratios of the monthly products of pain, fifteen years were taken, 1875–1889, inclusive, and the following is the order, beginning with the highest: February, .176; March, .175; January, .174; December, .168; November, .164; April, .161; May, .160; July, .159; June, .154; September, .153, and October, .153, in which we find January, February, and March about equal; then follow December, November, April, May, and July, leaving June, August, September, and October the least harmful.

By a reference to our last paper (p. 7, 1883), the order there given for monthly products of pain was corrected in proof, but the correction was omitted in some way. In that order as it stands no allowance was made, in determining the ratios, for the inequality in the number of days for the several months.

In the order as given above the ratio for February is obtained by dividing the total number of hours of neuralgia for this month—for the period of fifteen years—by the *whole* number of February days for the same period, and so on for each month.

TABLE A.

Month.	Barometer, 1875-1888, inclusive.		Mean hourly velocity of the wind, 1875-1885, inclusive.		No. of days on which rain fell 1875-1885, inclusive.		Relative humidity 1875-1885, inclusive.		Depth of rain 1875-1885, inclusive.		Monthly amounts of ozone, 1878-1885, inclusive.		Temperature, 1875-1881, inclusive.		Hours of sunshine, 1877-1881, inclusive.		Elastic force of aqueous vapor, 1875-1885, inclusive.		No. of storms 1875-1881, and May 1885-1888, inclusive.	
January	10	4	4	7	7	4	1	7	6	5	5	3	5	2	3	2	6	5	4	8
February	8	6	3	8	6	5	7	4	6	5	6	2	1	6	2	3	5	6	6	6
March	6	8	7	4	7	4	5	6	8	3	5	3	6	1	2	3	7	4	10	2
April	10	4	6	5	9	2	9	2	8	3	2	6	..	7	..	5	2	9	5	7
May	7	7	7	4	4	7	7	4	7	4	5	3	3	4	2	3	1	7	8	4
June	9	5	8	3	6	5	7	4	6	5	5	3	2	5	2	3	6	5	7	5
July	9	5	5	6	8	3	9	2	7	4	6	2	2	5	2	3	7	4	5	8
August	6	8	2	9	8	3	5	6	6	5	5	3	4	6	2	3	5	6	7	6
September	8	6	5	6	9	2	7	4	9	2	7	1	4	3	4	1	6	5	7	6
October	9	5	8	3	6	5	4	7	5	6	5	3	4	3	3	2	5	6	6	7
November	8	6	5	6	5	6	5	6	7	4	6	2	3	4	3	2	6	5	10	3
December	8	6	7	4	7	4	6	5	10	1	3	5	4	3	2	3	4	7	8	5
Percentage	56	44	51	49	62	38	57	43	64	36	63	37	42	58	45	55	48	52	56	44

TABLE B.—*Maximum neuralgia.*

Month.	No. of hours of neuralgia.	Departure from mean.							
		Barometer.	No. days of rain.	Depth of rain.	Relative humidity.	Depth of snow.	Temperature.	No. of storms.	Force of vapor.
January, 1875	202	+0·016	Mean	−0·41	+0·08	− 4·62	−5·56	+1·5	−0·019
November, 1875	190	+ ·159	−1·7	+ ·58	− ·06	− 1·30	−3·75	+3·00	− ·045
March, 1876	188	+ ·043	+ ·8	+5·00	− ·02	− 1·13	−1·50	+3·00	− ·015
January, 1877	242	+ ·024	−1·1	− ·96	+ ·02	+10·62	−1·75	+2·50	· ·012
March, 1877	188	− ·009	− 3·8	+1·74	+ ·06	+ 1·62	− ·10	+1·00	+ ·011
September, 1877	166	− ·018	−3·3	−2·25	− ·07	.....	+1·10	+7·50	+ ·017
March, 1878	152	− ·026	+ ·8	− ·59	− ·07	− 4·88	+8·00	+8·00	+ ·037
June, 1879	150	+ ·011	−5·0	− ·25	· ·06	.....	Mean	Mean	+ ·036
October, 1880	174	+ ·016	−1·8	− ·75	+ ·10	.....	−1·10	· 0·50	− ·022
March, 1884	164	+ ·007	+2·0	+ ·80	− ·05	− 2·63	+1·60	+1·00	Mean
July, 1884	152	− ·107	· ·8	+ ·40	− ·01	.....	−3·20	+3·00	− ·130
February, 1885	142	− ·130	− ·7	+ ·83	+ ·13	+ 5·75	−8·00	Mean	− ·021
Difference of departures		− ·014	+1·6	+4·13	+ · 09	.....	−14·20	+31·00	− ·119

TABLE C.—*Minimum neuralgia.*

Month.	No. hours of neuralgia.	Departure from mean.							
		Barometer.	No. days of rain.	Depth of rain.	Relative humidity.	Depth of snow.	Temperature.	No. of storms.	Force of vapor.
September, 1875	105	−0.060	− 1.35	− 1.69	+0.02	.....	− 1.85	− 1.1	−0.007
June, 1876	116	+ .017	− 1.00	− .74	+ .02	.....	+ 3.10	− 3.0	+ .073
July, 1876	111	− .009	− 2.20	− .68	+ .05	.....	+ 1.50	− 1.1	+ .051
October, 1876	105	− .097	· .20	− 2.14	+ .06	+ .48	− 4.19	− 1.5	+ .027
February, 1877	105	− .026	− 4.70	− 2.49	− .07	− 8.34	+ 6.12	Mean.	+ .015
June, 1878	90	− .046	− 2.00	− .32	− .01	.....	− 2.47	+ 1.0	− .054
May, 1880	103	+ .073	− 6.40	− 2.22	− .02	.....	+ 7.40	+ .8	+ .082
July, 1881	98	− .022	− 4.20	− 3.08	+ .03	.....	− 1.45	− 1.1	− .067
October, 1881	89	+ .070	− 2.80	− 1.96	+ .04	.....	+ 4.07	− 4.5	+ .069
November, 1882	100	+ .069	− 2.70	− 1.96	+ .11	+ 12.70	− 3.29	− 8.2	Mean.
February, 1883	88	+ .158	· 1.30	· .48	− .10	+ 1.42	− .63	− 1.5	− .022
August, 1881	80	+ .061	+ 3.20	+ 3.23	+ .03	.....	+ .85	+ .5	+ .022
September, 1885	53	− .034	− 3.35	− 3.17	+ .01	.....	− 1.40	− 2.1	− .011
Difference of departures	.....	+ .144	−26.00	−16.74	− .07	.....	+10.36	−24.8	+ .238

DIURNAL FLUCTUATIONS OF PAIN.

This brings us to a consideration of perhaps the most difficult and complex part of our study. The persistency of the type, for more than eighteen years, of these hourly beginnings of pain renders the curve in Fig. F of peculiar interest. We have asserted in previous papers that there are two subjective conditions which attend attacks of pain. The first one to attract our attention is the drowsy tendency *to sleep* preceding the attack, and this is equally true when the onset of pain is in the morning. I have no theory to account for this at all, but it seems to have a functional intimacy with the pain and was noted early in the history of this case more than twenty years ago. The other condition is the effect of *eating*, which emphasizes a case already on and may prematurely develop an attack which otherwise would have been delayed several hours.

In the daily pain curve we find three principal maxima, the first at 11 a. m., the second at 2 p. m., and the third at 7 p. m., with two subordinate ones at 9 a. m. and 4 p. m. Eating may possibly have something to do with the rise at 9 a. m., 2 p. m., and 7 p. m., but seems to bear no relation to the 11 a. m. maximum with a subordinate minimum at 10 a. m. intervening between it and the 9 a. m.

The part of the curve at 6, 7, and 8 a. m. has almost an inverse counterpart in 8, 9, and 10 p. m.; but to take the curve from 9 a. m. to 7 p. m., inclusive (leaving night out for reason previously given), we find one very important minimum at 12 and 1 p. m., then a subordinate minimum at 3 p. m., very like the 10 a. m., followed at 5 and 6 p. m. with a distinctly marked minimum.

We have placed on this pain curve two other curves constructed from Prof. Draper's record of sixteen years, from 1869 to 1884, inclusive, nearly all of which time is comprehended in the eighteen years' pain curve. The broken line is constructed on ordinates the lengths of which are the respective measures of the percentage of the number of times a storm began to rain on each hour. The unbroken line is similarly constructed and gives the percentage of depth of rain for each storm. The mean of each for the twenty-four hours is almost identical, but the mean of the *number of storms* for the period from 9 a. m. to 7 p. m., inclusive, is greater than the mean for the whole time, and the mean of the *rain depth* for same time is less than mean for the whole twenty-four hours.

While the absolute values of the rain depths and number of storms on the hours of greatest pain do not show a full correspondence, it is evident at once that there is a relative value between the storm and rain curves and the pain, and a parallelism of the two to the latter.

In all discussion of this subject to this time we have used only instrumental records, such as the synoptic charts, thermograms, etc., but we are aware that the physical effects produced by the temperature on the southeast side of a cyclone is very different from the same temperature on the west side. We have found that the eastern edge of the neuralgic crescent lies more than six hundred miles, or about twenty-three hours, to the east of the center of the "lows" as an average; but no two cyclones or rain conditions are exactly alike and have different kinds of rain, and when we consider that there are two atmospheres, one of a dry gaseous air and another one distinct of aqueous vapor, with the latter never thoroughly intermixed with the former and never in a state of equilibrium, we partially realize how impossible it is for any given storm to get a complete record by instruments and of those which are the best pain producers, for without apparent cause they vary much in this respect. No local hygrometric reading can give anything more than a vague approximation of the quantity of vapor or its mixture in a vertical column of air.

A typical neuralgic atmosphere anticipating a cyclone may be a dry air with a diminishing light, variable northerly to westerly winds, with a pale, delicate, bluish whiteness in the atmosphere, more marked as one's attention is drawn to the horizon and especially in the morning. The whiteness may increase for two days with an increasing discomfort when exposed to the peculiar penetrating power of the sun's rays, but during all this typical condition we have nothing which has measured the changing aspect of the air nor its changing diathermaneity; nor the absolute vapor, except at surface, nor its first faint speck of light cirrus in the milky whiteness, nor the distinctive character of the cyclone heat in the southeast quadrant, nor the direction of the upper and cross currents of wind, nor above all the modifications of the diurnal and "semi-diurnal" effect superimposed on the cyclone movement. It therefore seems probable that in the suc-

cessful study of this effect of climate or weather on health that we should supplement the meteorological charts by some descriptive narration to more nearly complete the record. Recurring again to the diagrams we find an increasing tendency to storm from early morning until 9 a. m., and then the slight break at 10 a. m. which has been recorded for other climates also, and then the increasing tendency up to the highest temperature and wind velocity of 2 o'clock followed in this record with more than a mean storm condition till 9 p. m.

CONCLUSION.

We have thus far, in all the various aspects of treatment of this case, found *weather* a factor more or less potent in the annual comparisons; in the semiannual, quarterly, and monthly, in the "spells" belonging to any "type," and in the diurnal we find correlation between pain and weather. And doubtless in the decennial periods, if such shall be demonstrated to exist, we should find a corresponding response.

In writing of this record, which was begun September, 1871, it may be proper to state that every effort has been made to eliminate all mental bias or preconceived notions of conclusions not warranted strictly by recorded facts. Facts themselves are very difficult to properly record, and require much thought and experience. Any testimony in regard to pain sensation is untrustworthy when memory is solely relied upon, and is hardly worth considering.

Finally, I desire to express my obligation to Gen. Greely, Chief Signal Officer, and Mr. Fassig, librarian of the Signal Bureau, for aid in use of much valuable manuscript, and also to Prof. Mendenhall, Superintendent Coast Survey, for valued suggestions.

Fig. I. Winter months—October-March, 10 for each month. 60.

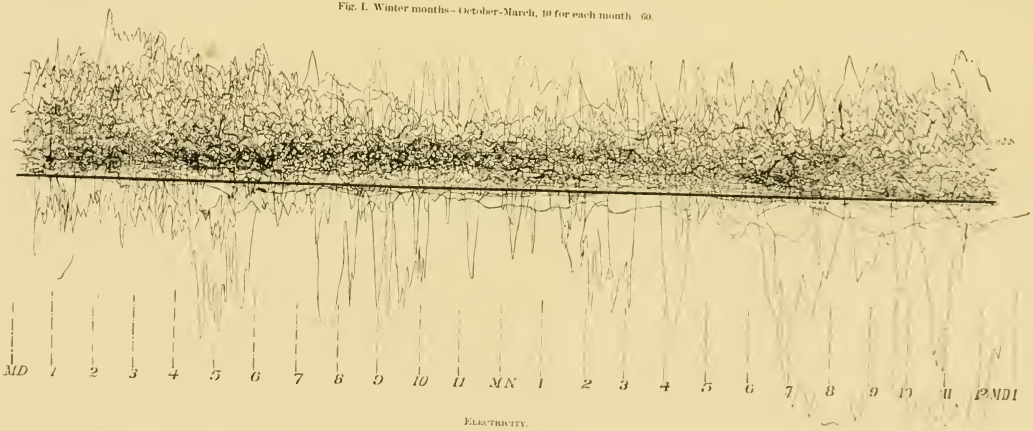


Fig. II. Six summer months—April-September, 10 for each month. 60

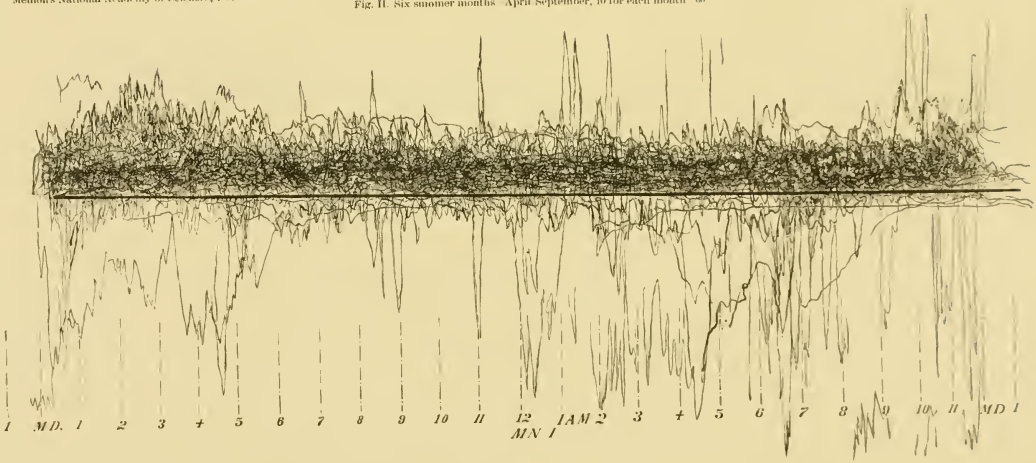
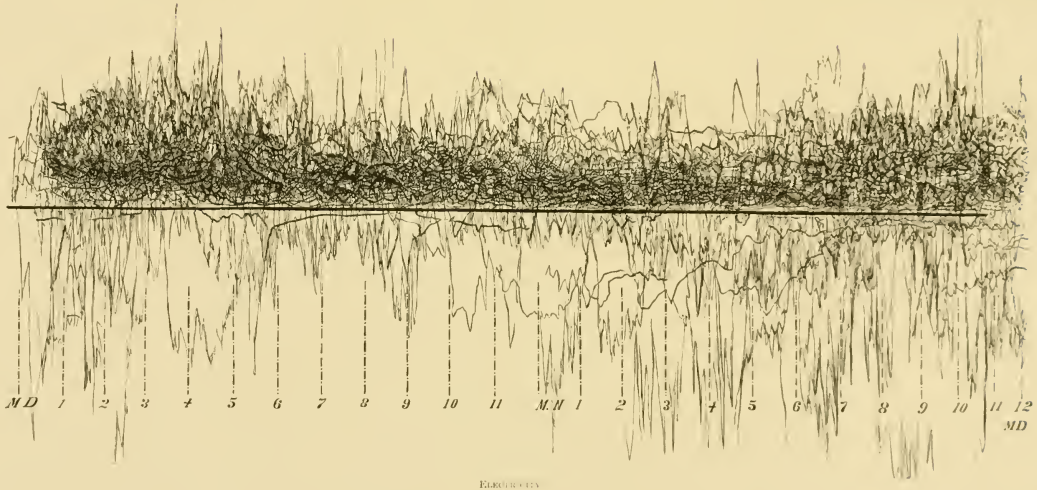
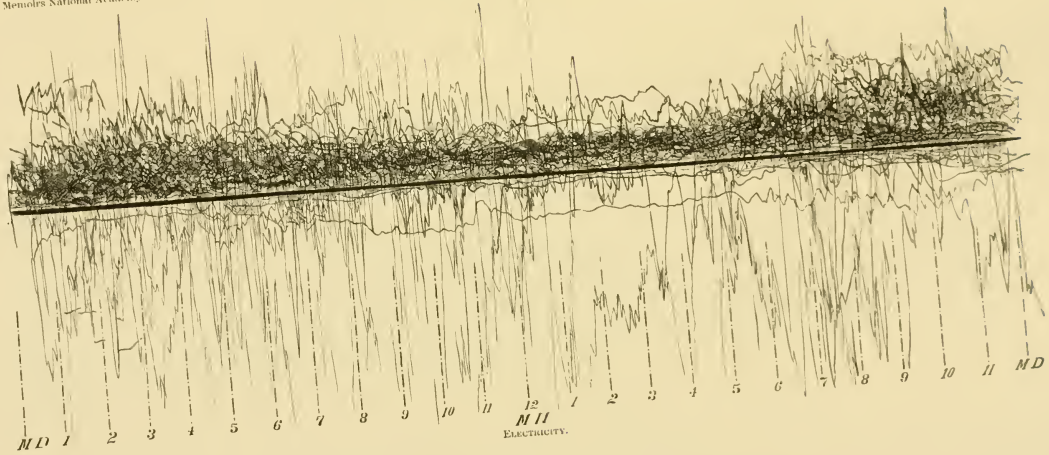


Fig. III



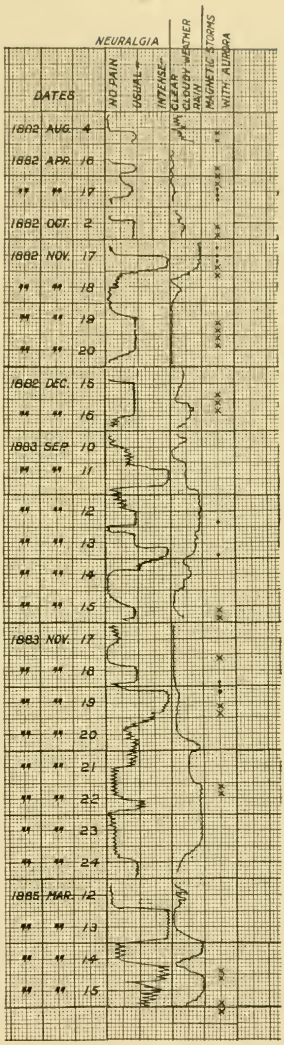
ELECTRICITY.

Fig. IV.



ELECTRICITY.

Fig. V


NEURALGIA
DATES
NO PAIN
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CLEAR
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1882 AUG. 4
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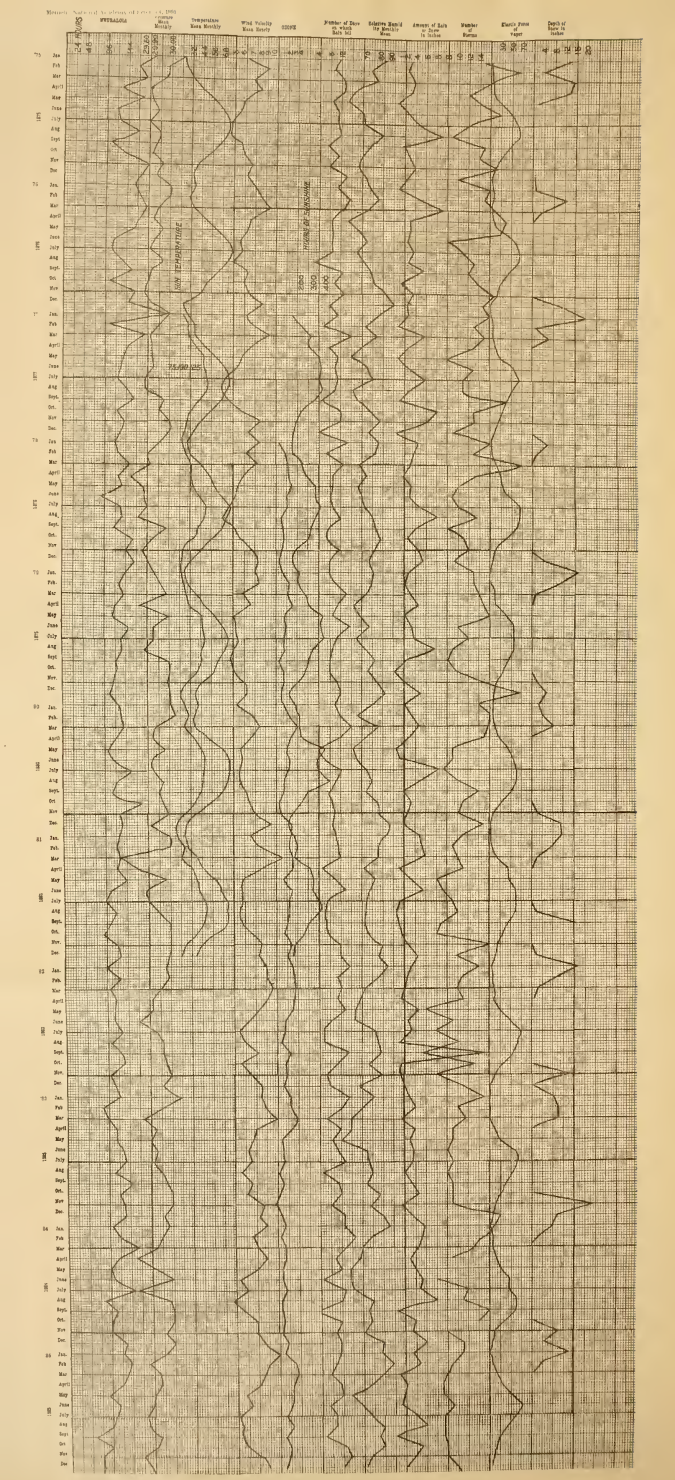
Missouri Botanical Garden, 1916



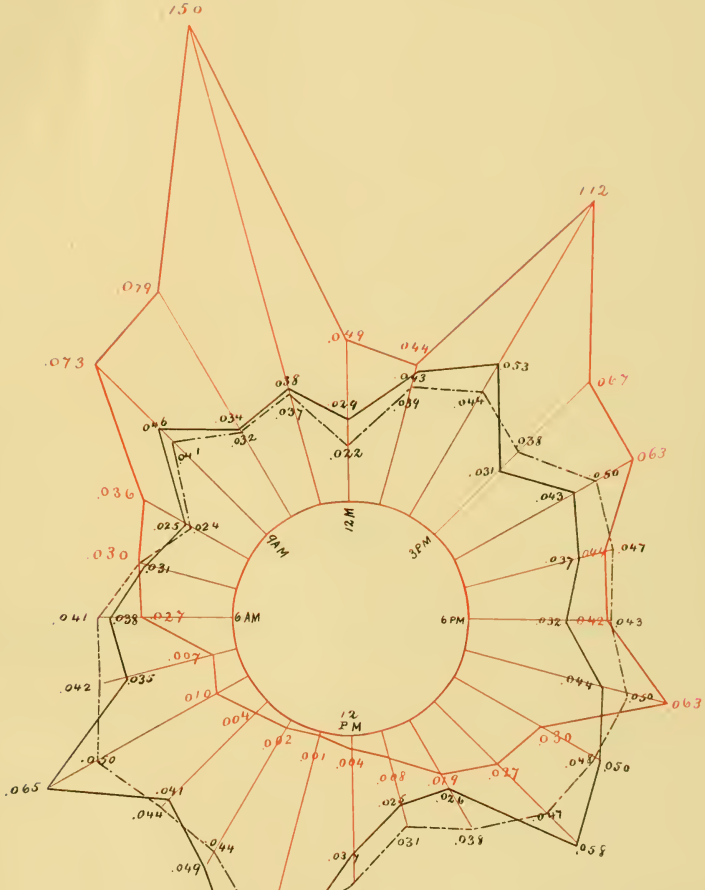


Fig. IV.

Red curve - Ratio of hourly beginnings of rain for 18 years - 1872-1889 inclusive

Broken black curve = Relative percentage of number of storms on each hour - 1869-1884 inclusive

Unbroken black curve = Relative per. ct. of depth of rain for each storm for the same 16 year period

NATIONAL ACADEMY OF SCIENCES.

VOL. VI.

THIRD MEMOIR.

ON CERTAIN NEW METHODS AND RESULTS IN OPTICS.

ON CERTAIN NEW METHODS AND RESULTS IN OPTICS.

CHARLES S. HASTINGS.

The usual formulas for the calculations of lens systems of any but those of the greatest simplicity are extremely complicated. Should such accuracy be desired as is absolutely requisite for the designing of optical apparatus, in which case the ordinary approximations are insufficient, the formulas become almost unmanageable.

The famous paper by Gauss, which was published in 1840, and which first introduced the conception of cardinal points in an optical system, was a very remarkable advance on the older theories. After its appearance it was possible to take into account the thicknesses and separations of the lenses with rigid accuracy without introducing greater complexity in the final equations than already secured by a method which assumed that these elements might be neglected. But even more important than this was his perfect definition of terms which had been used for ideal systems, but which could not have any exact meaning when applied to any physical apparatus, such as focal length, magnification, optical center. This paper, with Listing's addition of the two nodal points, left nothing to be desired in giving a complete and definite geometrical notion of an optical system whose cardinal points were known. But this is not the primary end in either designing an optical system nor in determining its optical efficiency when completed. The absolute focal length and magnification of any optical instrument is of the least possible consequence, as becomes at once obvious when we consider how few working astronomers or microscopists can give these data with precision for their own instruments.

What is necessary in designing an optical instrument is a knowledge of its aperture, in the more general sense, of the variation of its focal plane with varying wave length of light, of its spherical aberration, of the variation of the spherical aberration with varying wave length, and, if the character of the image remote from the axis is of consequence, the variation of the magnification with varying wave length, and, finally, its astigmatism. Neither the older methods nor that of Gauss define the first of these important quantities, except, of course, in the simple case of the telescope, nor are they convenient for calculating the others.

From the character of the quantities named above, it is obvious that their mathematical expressions must be for the most part of the nature of derivations from the fundamental equations. But all of the fundamental equations for lenses of sufficient exactness to be of the least value are so complicated that their derivations, at least, are quite valueless for practical purposes.

It occurred to the writer a good many years ago that greater simplicity might be attained in mathematical expressions for optical systems if the conceptions of rays, radii, and indices of refraction, the first of which at any rate is most artificial, were replaced by the more natural notions of wave and lens surfaces and light velocities, the surfaces being characterized by their curvatures rather than by their radii. This proved so highly satisfactory in practice that he has used no other method for a long time, but a serious attempt to find how far it would go in replacing the older method in formal optics; that is to say, how far it would be of interest independent of more practical advantages, was left until about a year ago. To show the results obtained, so far as the fundamental equations are concerned, is the object of the present paper, leaving the discussion of the derivative equations and their applications for another occasion.

I.—GENERAL EQUATIONS.

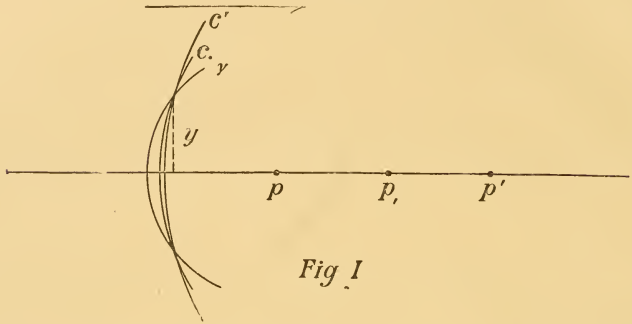


Fig I

Let p, $p_{,}$ and p' be respectively the geometrical centers of the lens surface, the incident wave surface, and the refracted wave surface; also let γ, c' and c_1 be the curvatures of these surfaces in order, a positive curvature corresponding to the case where the center of curvature is in the direction of propagation of light from the surface. Let x, x' and $x_{,}$ be the sagittas of these surfaces in order named, corresponding to the common semicord y; then for small values of y we have

$$x = \tfrac{1}{2}y^2\gamma, \qquad x' = \tfrac{1}{2}y^2c', \qquad x_{,} = \tfrac{1}{2}y^2c_1.$$

From the laws of wave propagation we have, if ρ represents the ratio of the velocity in the medium to the right of the surface γ to that in the medium to the left,

$$x - x_{,} = \rho\,(x - x').$$

Substituting the above values of x, x' $x_{,}$ in this equation, eliminating the common factor $\frac{1}{2}y^2$, and solving for $c_{,}$ we have

$$c_1 = \gamma\,(1-\rho) + \rho c'.$$

This wave surface will be propagated with uniform velocity and uniformly decreasing radius until it reaches the second refracting surface at a distance $t_{,}$ from the first, when its radius is reduced from $\dfrac{1}{c_{,}}$ to $\dfrac{1}{c_{,}} - t_{,}$ and therefore its curvature to the reciprocal of this, or to

$$\frac{c_{,}}{1-c_{,}t} = \mu' c_{,}$$

if we define μ' by this equation. After refraction at this second surface, the curvature will be according to exactly the same reasoning as that applied to the first surface,

$$c_2 = \gamma'\,(1-\rho') + \mu'\rho' c_{,}.$$

This completes the general solution, and it can be extended to any number of refractions, thus:

$$\begin{aligned}
c_1 &= \gamma\,(1-\rho) + \mu\rho c' & \mu &= 1\\
c_2 &= \gamma'\,(1-\rho') + \mu'\rho' c_1 & \mu' &= (1-c_{,}t_{,})^{-1}\\
c_3 &= \gamma''\,(1-\rho'') + \mu''\rho'' c_2 & \mu'' &= (1-c_2 t_2)^{-1} \qquad (a)\\
&\cdots\cdots\cdots\cdots & &\cdots\cdots\cdots\cdots\\
c_\lambda &= \gamma^{\lambda-1}\,(1-\rho^{\lambda-1}) + \mu^{\lambda-1}\,\rho^{\lambda-1}\,c_{\lambda+1} & \mu^{\lambda-1} &= (1-c_{\lambda-1}\,t_{\lambda-1})^{-1}\\
c_{\lambda+1} &= \gamma^{\lambda}\,(1-\rho^{\lambda}) + \mu^{\lambda}\,\rho^{\lambda}\,c_{\lambda} & \mu^{\lambda} &= (1-c_{\lambda}\,t_{\lambda})^{-1}
\end{aligned}$$

If the lenses are all indefinitely thin and in contact—in other words, if all the t's are equal to zero, and therefore all the μ's equal to unity, the equations (a) can be readily combined into one. This reduction, by inspection, is

$$c_{\lambda+1} = \gamma^{\lambda}\,(1-\rho^{\lambda}) + \gamma^{\lambda-1}(1-\rho^{\lambda-1})\,\rho^{\lambda} + \ldots\ldots\ldots + \gamma\,(1-\rho)\,(\rho^{\lambda}\,\rho^{\lambda-1}\ldots\ldots\rho') + \rho^{\lambda}\,\rho^{\lambda-1}\ldots\rho'\,c'.$$

If n_0 is the index of refraction of the first medium, n' in that of the second, and so on, we shall have

$$\rho = \frac{n_0}{n'}\ ,\quad \rho' = \frac{n'}{n''}\ \ldots\ldots\ldots\ \rho^{\lambda} = \frac{n^{\lambda}}{n^{\lambda+1}},$$

and the product of all these quantities will be equal to $\frac{n_0}{n^{\lambda+1}}$, which quantity, the ratio of light velocity in the last medium to that in the first, we will designate by $\rho_{\circ}$. By this substitution the above equation becomes:

$$c_{\lambda+1} = \mathrm{P} + \rho_{\circ}\,c',$$

where P is a constant, depending solely upon the physical constants of the system; it is called the *power* of the combinaton, not only because it is the change in curvature which the system can produce in a plane incident wave surface ($c'=0$), but also because in the most common of all cases in which the first and last mediums are alike, air, for example, and therefore $\rho_{\circ}=1$. P is the curvature which the system adds to every incident wave surface.

II—IMAGES AND MAGNIFICATION.

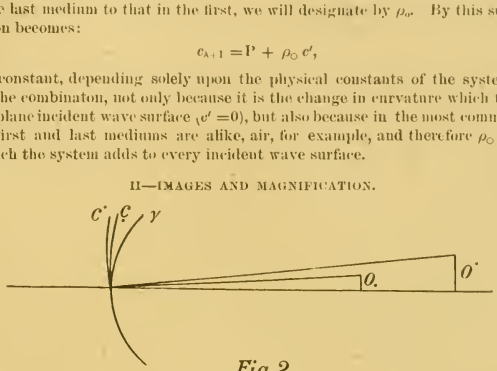


Fig 2

Let o' be the indefinitely small distance of the center of the incident wave surface c' from the axis and o_1 that of the center of the refracted wave surface c_1; then we have, from the general law of wave motion, the line o_1 is the image of o' and the angle which c_1 makes with γ at the vertex is ρ times that which c' makes at the same point, hence

$$\frac{o_1}{o'} = \rho\,\frac{c'}{c_1}\ .$$

The image of o_1 after refraction at a second surface we may call o_2, then by similar reasoning we have

$$\frac{o_2}{o_1} = \rho'\,\frac{\mu' c_1}{c_2}\ .$$

Extending this process to $\lambda+1$ refractions and collecting we have

$$\frac{o_1}{o'} = \rho\,\frac{c'}{c_1}$$

$$\frac{o_2}{o_1} = \rho'\,\frac{\mu' c_1}{c_2}$$

. . . . . .

. . . . . .

$$\frac{o_{\lambda}}{o_{\lambda-1}} = \rho^{\lambda-1}\,\frac{\mu^{\lambda-1} c_{\lambda-1}}{c_{\lambda}}$$

$$\frac{o_{\lambda+1}}{o_{\lambda}} = \rho^{\lambda}\,\frac{\mu^{\lambda} c_{\lambda}}{c_{\lambda+1}}$$

The product of these equations is, remembering that the product of all the ρ's is ρ_0:

$$\frac{o_{\lambda+1}}{o'} = \rho_0 \frac{c'}{c_{\lambda+1}} \left| \frac{\mu^\lambda}{\quad} \right|$$

The value of the factor $\left| \frac{\mu^\lambda}{\quad} \right|$ is easily changed by substituting successively the value of μ^λ and of c_λ given in (a), to the form

$$\left| \frac{\mu^\lambda}{\quad} \right| = \mu^{\lambda-1} \left| \frac{1}{1 - c_\lambda t_\lambda} \right| = \mu^{\lambda-1} \frac{1}{\alpha_{\lambda-1} + \beta_{\lambda-1}\, \mu^{\lambda-1} c_{\lambda-1}},$$

in which $\alpha_{\lambda-1}$ and $\beta_{\lambda-1}$ are constants depending solely upon the physical constants of the system and not at all upon the value of any of the wave curvatures. If we make another substitution of the values of $\mu^{\lambda-1}$ and of $c_{\lambda-1}$ in this last equation we have,

$$\left| \frac{\mu^\lambda}{\quad} \right| = \mu^{\lambda-2} \left| \frac{1}{\alpha_{\lambda-2} + \beta_{\lambda-2}\, \mu^{\lambda-2} c_{\lambda-2}} \right|$$

If we repeat this process of substitution λ times we shall have, finally

$$\left| \frac{\mu^\lambda}{\quad} \right| = \frac{1}{\alpha + \beta c'}$$

in which α and β are determinable functions of the γ's, the t's and the ρ's—that is, of the physical constants of the system, and the ratio of the ultimate image to the object, or the magnification, becomes

$$\frac{o_{\lambda+1}}{o'} = \rho_0 \frac{c'}{c_{\lambda+1}(\alpha + \beta c')} \tag{b}$$

There is, however, another very important expression for the magnification which may be derived as follows:

Suppose we have a diaphragm at the first surface with the small diameter $2a$. Let the semi-angular diameters of the wave surfaces, incident and refracted, thus limited be designated by ω' and ω_1, and so on for the successive refracting surfaces; then

$$\begin{aligned}
\sin\ \omega' &= a\, c' \\
\sin\ \omega_1 &= a\, c_1 \\
\sin\ \omega_1 &= a_1\, \mu' c_1 \\
\sin\ \omega_2 &= a_1\, c_2 \\
\sin\ \omega_2 &= a_2\, \mu'' c_2 \\
\sin\ \omega_3 &= a_2\, c_3 \\
&\cdots\cdots \\
\sin\ \omega_\lambda &= a_\lambda\, t^\lambda c_\lambda \\
\sin\ \omega_{\lambda+1} &= a_\lambda\, c_{\lambda+1}
\end{aligned}$$

From these we have

$$\begin{aligned}
\frac{\sin\ \omega'}{\sin\ \omega_1} &= \frac{c'}{c_1} && \cdots\cdots\cdots \\
\frac{\sin\ \omega_1}{\sin\ \omega_2} &= \mu' \frac{c_1}{c_2} && \cdots\cdots\cdots \\
\frac{\sin\ \omega_2}{\sin\ \omega_3} &= \mu'' \frac{c_2}{c_3} && \frac{\sin\ \omega_\lambda}{\sin\ \omega_{\lambda+1}} = \mu^\lambda \frac{c_\lambda}{c_{\lambda+1}}
\end{aligned}$$

The product of these equations gives

$$\frac{\sin\ \omega'}{\sin\ \omega_{\lambda+1}} = \frac{c}{c_{\lambda+1}} \left| \frac{\mu^\lambda}{\quad} \right|$$

Multiplying this equation by ρ_0 and observing (b) we have

$$\frac{o_{\lambda+1}}{o'} = \rho_0 \frac{\sin\ \omega'}{\sin\ \omega_{\lambda+1}} \tag{c}$$

This equation has been proved for small values of a only and would therefore hold good if either ω or $tg\ \omega$ were substituted for $\sin \omega$. In the last form, $tg\ \omega$ replacing $\sin \omega$, the equation was first given by Lagrange and was a most important contribution to the theory of optics; but it is possible to show that the form which we have given above is rigidly true, independently of the size of a, provided only that the incident and finally refracted wave surfaces are both spherical, *i. e.*, that the system is free from spherical aberration.

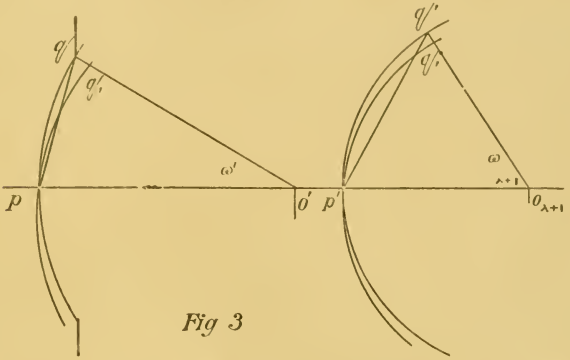


Fig 3

Let pq (Fig. 3) be the incident wave c' and $p'\ q'$ the finally refracted wave surfaces $c_{\lambda+1}$. If c' is limited by a diaphram at q, then $c_{\lambda+1}$ is also limited at a point q', which is the *corresponding* point to q; that is to say, the point in $c_{\lambda+1}$ where all the light energy comes from a region in c' indefinitely near q. Call the semiangular aperture of c' and of $c_{\lambda+1}$, ω' and $\omega_{\lambda+1}$, as indicated in the figure. Now suppose the incident wave to be inclined by an indefinitely small angle $o'c'$, then the finally refracted wave will also be inclined by an infinitely small angle at p', which will be equal to $o_{\lambda+1}\ c_{\lambda+1}$. It is apparent from the figure that in the new oblique waves q_1 is a *corresponding* point to q, since the wave surface is propagated in the direction of its normal, and, for the same reason, q_1' is a corresponding point to q', hence q_1' on the finally refracted oblique wave is a corresponding point to q_1. But since p and p' are corresponding points for both wave systems, the time required for light waves to pass from q to q' and from q_1 to q_1' is, in each case, equal to the time required in going from p to p'; hence the time required for progression from q to q_1 is equal to the time from q' to q_1'. The velocity of propagation is the last medium, however, is ρ_0 times as great as in the first; consequently we have

$$\rho_0 \cdot qq_1 = q'q_1'.$$

By inspection of the figure we see that

$$qq_1 = pq \cdot o'c' \cos \tfrac{1}{2}\ \omega'$$
$$q'q_1' = p'q' \cdot\ o_{\lambda+1}\ c_{\lambda+1} \cos \tfrac{1}{2}\ \omega_{\lambda+1}.$$

Combining these three equations and substituting the trigonometrical expression for the chords pq and $p'q'$, we have—

$$2\ \rho_0\ o' \sin \tfrac{1}{2}\ \omega' \cos \tfrac{1}{2}\ \omega' = 2\ o_{\lambda+1} \sin \tfrac{1}{2}\ \omega_{\lambda+1} \cos \tfrac{1}{2}\ \omega_{\lambda+1},$$

whence we derive immediately the equation (c).

This highly important relation is essential in calculating the absolute optical power of any optical apparatus except the telescope. Its truth was assumed by Prof. Abbe in his celebrated

paper on the limit of power in microscopes, and was proved very indirectly by Helmholtz in his paper on the same subject as a consequence of the second law of thermodynamics. I am not aware that any proof purely optical has heretofore been given.

III—SIMPLIFICATION OF GENERAL EQUATIONS (*a*).

In the discussion to this point we have made c' the curvature of the incident waves at the first vertex of the system and $c_{\lambda+1}$, the curvature of the finally refracted waves at the last vertex. We will now seek the relation of the curvatures for incident, and finally refracted wave surfaces at points situated, respectively, at a distance $x_\circ$ from the first vertex and x_1 from the last.

Let us suppose that the incident wave surfaces are bounded by a circular diaphram of radius a° at $x_\circ$, then the finally refracted wave surfaces will be also bounded and will have a definite semi-diameter at x_1, which we shall designate by $a^\circ{}_1$; then, if C' and C_1 represent the wave curvatures at the points $x_\circ$ and x_1 for incident and finally refracted waves, respectively, we have the following relations:

$$\sin \omega' = a^\circ C' \qquad c' = \frac{C'}{1+C'x_\circ}$$

$$\sin \omega_{\lambda+1} = a^\circ{}_1 C_1 \qquad c_{\lambda+1} = \frac{C_1}{1+C_1 x_1}$$

Substituting these values in (*c*) we have

$$\frac{c_{\lambda+1}}{c'} = \rho_\circ \frac{a^\circ C'}{a^\circ{}_1 C_1}$$

By replacing the left member of this equation by its value given in (*b*) and in the latter the values above for c' and $c_{\lambda+1}$ we have

$$\frac{a^\circ}{a^\circ{}_1} = \frac{1+C_1 x_1}{\alpha+(\alpha x_\circ+\beta)C'}$$

whence the value of C_1 is given by the equation

$$C_1 = \frac{\dfrac{a^\circ}{a^\circ{}_1}\alpha - 1}{x_1} + \frac{\alpha x^\circ + \beta}{x_1}\frac{a^\circ}{a^\circ{}_1}C'$$

If $x_\circ$ and x_1 are so chosen that one is the optical image of the other, $\dfrac{a^\circ}{a^\circ{}_1}$ becomes a constant since $a^\circ{}_1$ is simply the image of a°, and the expression for C_1 becomes greatly simplified. We will call the value of $\dfrac{a^\circ}{a^\circ{}_1}$ for any such case k. This value can be found by substituting $\dfrac{1}{x_\circ}$ and $\dfrac{1}{x_1}$ for c' and $c_{\lambda+1}$ in equation (*b*), whence, remembering that a° corresponds to o', we have

$$\frac{a^\circ{}_1}{a^\circ} = \frac{1}{k} = \rho_\circ \frac{x_1}{\alpha x_\circ + \beta}$$

We have also the following relations: When $C'=o$ $c'=o$ also, that is, if the incident waves are flat when they reach $x_\circ$, they are also flat at the first vertex. Call $c^\circ{}_{\lambda+1}$ the value of the finally refracted waves as computed from the equations (*a*) under the supposition that $c'=o$; then substituting this and the value $\dfrac{k\alpha-1}{x_1}$, the corresponding value of C_1, in the above equation connecting $c_{\lambda+1}$ and C_1 we find

$$\frac{k\alpha-1}{x_1} = k\alpha c^\circ{}_{\lambda+1}.$$

Substituting these expressions in the general equation we have this remarkably simple expression to replace equations (*a*)—

$$C_1 = k\alpha c^\circ{}_{\lambda+1} + \rho_\circ k^2 C'. \qquad (d)$$

Before discussing the methods for finding the contents k, α, and $c^\circ{}_{\lambda+1}$ in this general equation we will first establish expressions for the magnification and for the change in direction of the wave surface in progressing from $x_\circ$ to x_1.

The term magnification has two distinct meanings, namely, the ratio of the dimension of the images to that of the object measured at right angles to the axis, and a corresponding ratio in the direction of the axis. The first we may call the transverse magnification and designate M; the other may be called the longitudinal magnification and designated L.

From the fifth equation on page 42 we may write at once the value for the first species of magnification. It is equal to

$$M = \mu_0 k \frac{C'}{C_1} \qquad (e)$$

The longitudinal magnification is obviously equal to the ratio of the displacement of the image along the axis to the corresponding displacement of the object. From this definition and equation (d) we find

$$L = \frac{\alpha \frac{1}{C_1}}{d \frac{1}{C'}} = \frac{dC_1}{d(\alpha' C_1^2)} = \rho_0 k^2 \frac{C'^2}{C_1^2}$$

From these two equations we find

$$L = \frac{M^2}{\rho_0}. \qquad (f)$$

This law explains why the depth of field in microscopic vision seems so small, and also why an object under the microscope appears so much flatter when mounted in a medium of high refractive power, for in this case ρ_0 is greater than unity.

A consideration which is of much importance is the relation of the directions of the wave surfaces. This relation is readily determined for the points x_0 and x_1. In Fig. 3 let p and p' be the points x_0 and x_1, respectively, then, since by definition p' corresponds to p we need make no restrictions as to the value of the angles of inclination of the oblique wave surfaces. Call these angles φ_0 and φ_1 respectively, then, if pq is small, we have, as before,

$$\rho_0 qq_1 = q'q'_1$$

and

$$qq' = pq \sin \varphi_0$$
$$q'q'_1 = p'q' \sin \varphi_1 .$$

and finally, since $p'q'$ is the image of pq

$$\frac{pq}{p'q'} = k .$$

From these equations we read at once

$$\frac{\sin \varphi_1}{\sin \varphi_0} = k\rho_0 \qquad (g)$$

IV—TO FIND THE VALUES OF THE CONSTANTS IN EQUATION (d).

There are two cases presented in practice: First, when all the constants of the optical system are given, and, second, when we can only depend upon measurements as applied to the system as a whole. We shall consider these two cases in turn.

Case 1.—All the constants of the system being known compute $c^0{}_{\lambda+1}$ by making c' equal to zero in equations (a); the value of α is one divided by μ_λ in this computation.

To find k we either assume the value of x_0 and thence compute x_1 and k, or, assuming the value of k, compute x_0 and x_1 .

For the first method make $c' = \frac{1}{x_0}$ in (a); the resulting value of $c_{\lambda+1}$ equals $\frac{1}{x_1}$, and, substituting these values of c' and $c_{\lambda+1}$ in (b), remembering that $(\alpha+\beta c')$ is one divided by μ_λ we find the reciprocal of k at once. The solution is therefore complete.

If k is assumed, we compute $c^0{}_{\lambda+1}$ and α as before, then

$$x_1 = \frac{k\alpha - 1}{k\alpha c^0{}_{\lambda+1}}$$

whence we find x_0 from (a) by making $c_{\lambda+1} = \frac{1}{x_1}$ when $x_0 = \frac{1}{c'}$

Case 2.—Should we desire to find the constants of (d) by experiment, proceed as follows:

Choose any convenient point in the axis of the system for x_0, placing there an object, *e. g.*, a scale of equal parts; the image of this object will be at x_1 and the ratio of the size of the object to the image will be k. Then find the place on the axis of the image of an object at an indefinitely great distance in front of the system, that is when $C'=0$. The reciprocal of the distance of this point from x_1 equals $k\alpha\epsilon^0{}_{\lambda+1}$, and the problem is solved.

V.—ON PARTICULAR VALUES OF k IN EQUATION (d).

Inspection of the equation (d) suggests at least four values of k, which make the equation of special simplicity. These values are 1, -1, $\frac{1}{\rho_0}$ and $\frac{1}{-\rho_0}$. Substituting these in turn we have

$$\begin{aligned} C_p &= \alpha\epsilon^0{}_{\lambda+1} + \rho_0 C^p && (d^{\mathrm{i}}) \\ C_{-p} &= -\alpha\epsilon^0{}_{\lambda+1} + \rho^0 C^{-p} && (d^{\mathrm{ii}}) \\ \rho_0 C_n &= \alpha\epsilon^0{}_{\lambda+1} + C^n && (d^{\mathrm{iii}}) \\ \rho_0 C_{-n} &= -\alpha\epsilon^0{}_{\lambda+1} + C^{-n} && (d^{\mathrm{iv}}). \end{aligned}$$

The points defined by x_0 and x_1 when $k=1$ are called the first and second principal points, respectively. They were first introduced and their properties defined by Gauss, in a celebrated paper published in 1840. We see at once that the image of a small object at x_0 is at x_1, the transverse magnification is 1, and the longitudinal magnification is, from (f), $\frac{1}{\rho_0}$. The inclination of the incident wave at x_0 and the finally refracted wave at x_1 is given by (g) which becomes

$$\frac{\sin\varphi_1}{\sin\varphi_0} = \rho_0.$$

For $k=-1$, the second of the above equations, the points x_0 and x_1 are called the first and second negative principal points. An object at x_0 has its image at x_1, the image being inverted, but of the same transverse dimensions as the object; the longitudinal magnification is the same as before, namely, $\frac{1}{\rho_0}$. Finally (g) gives

$$\frac{\sin\varphi_1}{\sin\varphi_0} = -\rho_0.$$

For $k=\frac{1}{\rho_0}$, the two points x_0 and x_1 are called the nodal points. These were first investigated and named by Listing in 1851. An object at the first nodal point has its image at the second nodal point, both axial and transverse magnifications being equal to ρ_0. These are the only two points so related that the image of a body at one point has the same shape and orientation as the body itself. A more important property is derived from equation (g), in which we see for this case

$$\frac{\sin\varphi_1}{\sin\varphi_0} = 1$$

that is, a wave surface which would pass through the first nodal point at an inclination φ_0 passes through the second nodal point under the same inclination after final refraction.

The final form, in which the points x_0 and x_1 may be called the negative nodal points, has the same longitudinal magnification for these points, but the transverse magnification and the relation of the inclinations are equal to those of (d^{iii}) taken negatively.

It will be observed that (d^{i}) is of exactly the same form as the equations for a system of infinitely thin lenses in contact. Moreover, if the first and last mediums are alike—in which case $\rho_0=1$—equations (d^{i}) and (d^{iii}) become identical, as do also (d^{ii}) and (d^{iv}), or, in words, the principal and nodal points fall together, and also the negative principal and negative nodal points.

The determination of the position of all these points is the problem, when the constants of the system are known, of Case 1 of the preceding section, and therefore need not be further discussed. But to determine them experimentally is not the same as Case 2, because they assume determinate values for k. We may proceed as follows:

If both principal points are outside of the system and on opposite sides we may find them at once by seeking the places of object and image when the image is erect and equal in size to the

object. This process is applicable to some forms of compound microscope—such as that which is used as a terrestrial ocular in the telescope—but is very exceptional. In practically every other converging system the negative principal points will be outside the system and on opposite sides. Find these and the two principal focal points, then, as we see from $(d^{\rm I})$ and $(d^{\rm II})$ the principal focus is exactly half way between the principal point and the corresponding negative principal point.

The method of finding the four nodal points is precisely similar, except that the magnifications are taken as ρ_0 and $-\rho_0$ instead of 1 and—1, as in the case of the four principal points.

VI.—MAGNIFICATION OF OPTICAL SYSTEMS.

The general expression for the magnification is equation (c), which can, of course, be modified so as to be given in terms of the distance of the object from x_m, or from the first vertex of the system, or indeed from any other point fixed with respect to the system. But it is not easy to see that this would be of any practical interest. A photographer may desire a definite ratio of the image in his camera to the size of the object, and no doubt he could tell at once how far the object must be from the camera to give this ratio, if he had determined the value of k for two determinate positions of x_0 and x_1; but his method in practice of moving the instrument with respect to the object until the image becomes of the desired size would involve no more measurements than that of a single distance, which would also be necessary in the more recondite method.

For instruments used as aids to vision, however, the expression for magnification becomes particularly interesting, or rather the expression for angular magnification, since we care nothing for the absolute size of any image in question.

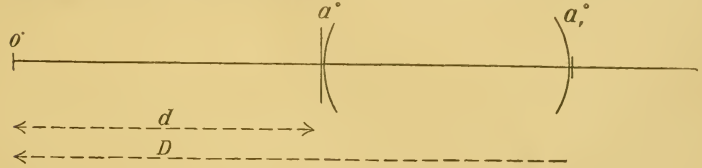


Fig 4

Let Fig. 4 represent any optical apparatus to be used as an aid in seeing $0'$. Let a^0 be an object in such a place that its image is at a^0_1 and very near the place of the eye. Call the distance from the eye to the object D, and the distance from a^0 to the object d, as represented in the figure. If d is very large, the instrument is called a telescope; if small, a microscope; when neither one nor the other, we have no name for it. For example, the instruments employed as optical aids in reading the distant circles of an equatorial may be called with equal propriety telescopes or microscopes. In short, there is no precise distinction between the two types and a general equation of the magnifying power ought to be applicable as well to one as the other.

We will define the magnifying power of such an instrument as the ratio of the apparent dimensions of a small object in the axis, as seen through the instrument, to that of the same object seen without the instrument.

From the diagram we see that the angular dimension of $0'$, as measured from a^0, is $\frac{0'}{d}$, which is also twice the angle φ_0 for the point of the object farthest from the axis. The angular subtense of the object, as seen from a_1^0 through the instrument is $2\varphi_1$, while the value of this angle without the instrument is $\frac{0'}{D}$, as is evident from the figure. This angle we will call 2Φ. The magnifying power is therefore equal to

$$\frac{\varphi_1}{\Phi}$$

But from (g) we see that $\varphi_1 = \rho_0 \frac{a^0}{a^0_1} \frac{0'}{d}$, whence, dividing by the value of Φ, the magnifying power becomes

$$\rho_0 \frac{a^0}{a^0_1} \frac{D}{d}$$

as a perfectly general expression.

For the telescope proper, $\rho_0 = 1$ and $\frac{D}{d} = 1$ also, since the length of the instrument is negligible with respect to the distance of the object. In this case the expression reduces to $\frac{a^0}{a^0_1}$, or, if we make a^0 equal to the diameter of the objective, it is equal to the quotient derived by dividing the diameter of the objective by the diameter of its image produced by the ocular, an old rule first given, I believe, by Ramsden.

For the microscope the magnifying power is defined somewhat differently from our definition above, namely, as the ratio of the apparent size to the size as seen at a distance of ten inches, which is $\frac{10^{in}}{D}$ times as great as ours. Thus modified the expression becomes

$$n \frac{a^0}{a^0_1} \frac{10^{in}}{d},$$

since ρ_0 becomes the same as the index of refraction of the "immersion fluid" employed. Not only this, but we have also $\frac{1}{2} \frac{a^0}{d}$ is the tangent of one-half the so-called "angular aperture," whence the true aperture equals

$$n \sin \left\{ tg^{-1} \frac{a^0}{2d} \right\}$$

It has long been known that the complete optical power of a telescope—that is, both its magnifying power and resolving power—could be determined by two linear measurements, the a^0 and a^0_1 of our discussion, but it has, perhaps, not been suspected before that with three linear measurements it is possible to determine both the magnifying power and resolving power of a microscope.

To illustrate the application of these formulas, we may quote the determinations of the optical constants of a Zeiss microscope employed with ocular No. 2, shortest tube, and three different objectives. The objectives were, a Zeiss *A*, of which his catalogue gives magnification 52 and numerical aperture 0.20, a $\frac{1}{4}^{in.}$ objective made by the writer, and a $\frac{1}{10}^{in.}$ Wales water immersion. The measures were made by placing a glass scale upon the table of the microscope and bringing the objective into contact with it, the number of divisions of the scale visible above the ocular, and also the absolute length of its image was then recorded, the former length being a^0 and the latter a^0_1. Then the tube was raised a measured distance (d) until the scale was in focus. In the table the measures are in millimeters. M is the calculated magnification and A the aperture.

Objective.	n.	a^0.	a^0_1.	d.	M.	A.
Zeiss *A*	1.00	3.5	2.0	8.5	52	.201
$\frac{1}{4}^{in.}$	1.00	3.3	1.7	3.5	140	.435
$\frac{1}{10}^{in.}$ immersion	1.33	1.1	1.5	0.48	351	0.99

It should be noted that, in order to determine M with precision, the ratio of a^0 to a^0_1, near the axis, should be taken, since the surface a^0 of Fig. 4 is not plane, but a portion of a wave surface. For small apertures this distinction is insignificant.

To investigate the resolving power of an optical apparatus used in conjunction with the eye we may proceed as follows:

Suppose that we have a plane area at a distance of 10 inches from the eye divided into regular spaces, and that we observe it through a hole of diameter a^0_1. The smallest angular values of the

elements of which the field is made and which can still be distinguished as separate elements is about $4''.5\,\frac{1^{in}}{a^0_1}$, if a^0_1 is measured in inches. This is proved in all works on the wave theory of light and is in accordance with experience. Now this supposition corresponds precisely with the conditions of vision through an optically perfect apparatus of the type under consideration, save that the field is magnified in the ratio $\frac{a^0}{a^0_1}$ for the telescope and $n\,\frac{a^0}{a^0_1}\,\frac{10^m}{d}$ in those systems when d is not indefinitely great, consequently in such cases the fineness of division of the field may be increased in these ratios. Hence the defining power of a telescope may be expressed by

$$4''.5\,\frac{1^m}{a^0_1}\,\frac{a^0_1}{a^0}=4''.5\,\frac{1^m}{a^0}$$

and in the other class by

$$4''.5\,\frac{1^m}{a^0_1},\quad \frac{a_1{}^0 d}{n\,a^0\,10^m}=4''.5\,\frac{d}{10\,n\,a^0}.$$

The former of these equations is a familiar one and need not be further discussed, but the latter contains the whole theory of the defining power of the microscope, and is therefore worthy of a brief consideration.

From what appears in the discussion of the relation of a^0_1 to a^0 we see that the former is the image of the latter, and also that a^0_1, being a portion of the incident wave surface, is not plane as is, very nearly, a^0_1. We see, moreover, that the greatest possible diameter of a^0 is $2d$, in which case the incident wave surface would be hemispherical, whence the maximum possible resolving power of a microscope is

$$\frac{4''.5}{20\,n}.$$

To reduce this to linear value we have only to multiply by 10^m, whence we have, as the closest lines which can be resolved by a microscope

$$2''.25\,\frac{1^{in}}{n}=0.^{in}000011\,\frac{1}{n},$$

in other words the finest divisions which can be seen with any microscope in which the objective is "dry" are about 100,000 to the inch, which, for a "homogeneous immersion" objective may rise to 150,000. Since the greatest value known for n in any transparent medium is about 2.5 we may say with certainty that there is no hope of ever making a greater number of lines than a quarter of a million to the inch visible.

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THE PROTEIDS OR ALBUMINOIDS OF THE OAT KERNEL.

THE PROTEIDS OR ALBUMINOIDS OF THE OAT KERNEL.*

By Thomas B. Osborne.

I.—Historical.

The proteids contained in or derived from the oat grain have been specially studied by J. P. Norton, Baron von Bibra, and Dr. W. Kreusler. Norton† recognized three proteids, viz, (1) *albumin*—0.5–2.17 per cent—which was taken up from the "epidermis" (after starch had been mechanically removed by elutriation with slightly ammoniacal water), by boiling with acetic acid, and was precipitated by neutralizing the solution; (2) *casein* (or *avenine*, as Johnson, in whose laboratory the work was done, named it)—15.76–17.72 per cent—which was dissolved in the slightly ammoniacal water used in separating starch, and thrown down by acetic acid; (3) *glutin*—1.33–2.47 per cent—extracted by alcohol and separated from oil by means of ether, and from sugar by water.

Von Bibra‡ found that no coherent gluten could be got from oat flour by kneading in water. He recognized *albumin*—1.24–1.52 per cent—precipitated by boiling the cold-water extract of the ground oats; *casein*—0.15–0.17 per cent—the body separating from the hot alcohol extract on cooling; *plant gelatin* (Dumas' *glutin*, Taddei's *gliadin*)—3.00–3.25 per cent—the substance soluble both in hot and cold alcohol; and *nitrogenous substance insoluble in water and alcohol*—11.38–14.85 per cent.

Kreusler§ found *oat gliadin*, soluble in weak alcohol and *oat legumin*, soluble in very dilute alkali.

Since the date of Kreusler's work, 1869, our knowledge of proteid bodies and of the methods for their investigation has been considerably extended. This advance has been chiefly in the study of the animal proteids, but little real progress having been made in our knowledge of the vegetable albuminoids. The following research was undertaken with a view to applying the newer methods of study to the plant proteids that have agricultural importance.

II.—Oat Proteids Extracted by Weak Alcohol.

(*a*) Kreusler's work.

The oat proteid soluble in weak alcohol was first examined, and, as results differing from Kreusler's were obtained, it will be well to give here a brief summary of his work.

Kreusler found that, on extracting ground oats with alcohol of 80 per cent and concentrating the extract to one-third of its volume, a considerable amount of substance separated which, after subsiding from the solution, became a tough, transparent mass of amber-yellow color. The solution decanted from this substance and further concentrated yielded a second deposit. The liquid poured from this second deposit yielded, on still further concentration, a third. The three sediments were united and dissolved in 80 per cent alcohol at a gentle heat. On cooling, the greater part of the substance precipitated. After decanting the liquid, this precipitate was treated with absolute alcohol, which caused it to gather on the walls of the vessel as a tenacious mass. After treating with ether and again with absolute alcohol, it was dried over sulphuric acid. This Kreusler designated "A."

* Presented to the National Academy of Sciences, in Boston, November 13, 1890, and New York, November 10, 1891.

† Am. J. Sci. [2] 3, 330 (1845); 5, 22 (1848).

‡ Die Getreidearten und das Brod (Nürnberg, 1860).

§ J. prakt. Chem. 107, 17.

By concentrating the solution decanted from A, on cooling, he obtained a second precipitate, "B." The filtrate from B by similar treatment yielded a third precipitate, "C."

These three precipitates showed the same behavior with various reagents and appeared to differ only in their degree of purity. The reactions agreed with those of gliadin from wheat, which, according to Ritthausen, contains 18 per cent of nitrogen.

Kreusler found that—

A contained 16.22 per cent of nitrogen.
B contained 16.21 per cent of nitrogen.
C contained 15.36 per cent of nitrogen.

These three preparations were united, dissolved in dilute acetic acid, and fractionally precipitated by dilute potash. Thus were obtained three precipitates—

I with 16 per cent of nitrogen.
II with 16.51 per cent of nitrogen.
III was too small in amount for analysis.

By this treatment the substance was separated into two portions of different nitrogen content

Kreusler in the next place prepared a new extract with alcohol of 80 per cent from 5 pounds of ground oats, concentrated the solution until nearly all the alcohol was removed, and on cooling, and treating the precipitate with ether and absolute alcohol and drying over sulphuric acid, obtained 30 grams of substance having properties like the former preparations, but not wholly soluble in acetic acid. This precipitate contained 15.36 per cent of nitrogen. When it was heated with acetic acid, a residue was left having 14.81 per cent of nitrogen. The acetic-acid solution by three partial precipitations with dilute potash gave, as before, precipitates I, II, and III—the third being too little for analysis. The composition was—

	I.	II.
Carbon	.....	53.41
Hydrogen	.....	7.15
Nitrogen	16.99	17.14

This treatment, however, had failed to yield a product having as much nitrogen as Ritthausen's gliadin.

I and II were, therefore, united and dissolved in 60 per cent alcohol at a gentle heat. The solution was brownish yellow, and on cooling a part of the substance precipitated. The filtrate from this precipitate gave a second precipitate when treated with absolute alcohol. These precipitates were united and called A. The alcoholic filtrate contained a considerable amount of substance, which was separated by concentration and gradual precipitation with absolute alcohol. This precipitate was marked B and resembled A in appearance. They contained—

	A.	B.
Carbon	.....	52.64
Hydrogen	.....	7.66
Nitrogen	17.71	16.70

Since the substance was precipitated in the presence of a considerable amount of acetic acid, and might be thought to retain some of the latter, the just-described process was repeated with A, and potash added to perfect neutralization. The precipitate thus obtained was slightly washed with water, and after dissolving in 60 per cent alcohol was precipitated with absolute alcohol. B was dissolved directly in weak, and precipitated by absolute alcohol. These products then had the following composition:

	A.	B.
Carbon	52.94	53.12
Hydrogen	7.71	8.15
Nitrogen	{ 17.28 { 17.30	17.20

These preparations were next united and dissolved by heating in 60 per cent alcohol; a varnish-like mass deposited on cooling. This process was repeated several times, and the substance was finally dried with absolute alcohol. It had the following composition, as found in analyses I and II:

			Gliadin.	
	I	II	Oats (Kreusler)	Wheat (Ritthausen)
Carbon	52.91	52.59	52.59	52.60
Hydrogen	7.58	7.65	7.65	7.00
Nitrogen	17.71	.....	17.71	18.06
Sulphur	1.71	1.61	1.66	.85
Oxygen	20.06	.....	20.39	21.49
	100.00	.....	100.00	100.00

The alcoholic solution after concentrating gave on cooling a preparation with 17.2 per cent nitrogen. Kreusler rejected the highest carbon determination (obtained without the use of lead dioxide) as probably erroneous, and wrote his analysis of *oat gliadin* beside Ritthausen's of *wheat-gliadin*, as quoted above. Kreusler concludes that oat-gliadin is essentially different from wheat-gliadin, and compares at length the behavior of the two towards reagents. The one point of difference he mentions is that the oat-gliadin dissolves in concentrated hydrochloric acid to a scarcely-colored liquid, while wheat-gliadin gives a blue solution.

It is evident from Kreusler's paper that he expected to find the oat-proteid soluble in alcohol to have the same composition as wheat-gliadin. He finally accepted, as pure, a preparation having 17.71 per cent of nitrogen, according to a single determination.

It is to be noticed on reviewing his analyses that the treatment to which Kreusler submitted his preparations, while on the whole tending to raise the nitrogen content, sometimes appears to have had the opposite effect, and the conclusion is not improbable that the fluctuations in the percentage of nitrogen found by him are partly attributable to the then unknown errors involved in the soda-lime method of analysis—errors which Ritthausen* and U. Kreusler† in later years fully appreciated and made the subject of special investigation.

III.—Oat Proteids Extracted by Weak Alcohol.

(*b*) the writer's work.

1. direct extraction with alcohol.

Preparations 1–8.

As Ritthausen had separated the gliadin, mucedin and fibrin found by him in wheat gluten, from alcoholic solution by fractional precipitations, the writer judged that if more than one proteid were extracted from oats by alcohol, this fact would be shown by differences in behavior and composition of various fractions of the alcoholic extract. Accordingly four kilos of freshly ground oats were heated on the water-bath with ten liters of alcohol of 0.915 sp. gr. After boiling for half an hour the extract was strained through cloth, the residue pressed out and the extraction repeated. The extracts were united, allowed to stand over night, decanted from sediment and filtered clear. This solution was concentrated to one-third by distillation. After standing for twenty hours at the temperature of the room, the residue deposited a bulky, yellowish precipitate. About four-fifths of the solution was carefully decanted from this precipitate. The remaining one fifth could not be filtered until a large amount of strong alcohol had been added, which caused the precipitate to separate. After filtering, the precipitate was treated with absolute alcohol, next with ether, and after removing the ether with absolute alcohol again, and dried over sulphuric acid. This preparation, "1" then weighed 15.5 grams and, dried at 110° C., contained 13.92 per cent of nitrogen. The liquid decanted from 1 was still further concentrated to about one-third of *its* volume and cooled. The precipitate which formed "2" was treated with ab-

*Pflüger's Archiv 18 236 (1878). †Landw. Vs-St. 24, 37 (1880); ibid. 31, 248 (1885).

solute alcohol and ether, and, after drying over sulphuric acid, weighed 10.30 grams. Dried at 110° C., it contained 12.36 per cent of nitrogen. The filtrate from **2** was concentrated to a thick sirup. On cooling, a deposit formed on the bottom of the dish. The sirup was poured off and this deposit treated successively with strong alcohol, absolute alcohol, ether, and finally with absolute alcohol again. After drying over sulphuric acid, this precipitate, "**3**," weighed 6.82 grams, and contained, when dried at 110° C., 10.37 per cent of nitrogen.

The alcoholic liquids obtained by washing preparations **1**, **2** and **3** were found to have dissolved a large amount of proteid; they were, therefore, united and concentrated on the water bath to small volume, and cooled. The abundant deposit was washed with absolute alcohol, ether, absolute alcohol again, and dried over sulphuric acid. The 14.62 grams thus obtained, "**4**," when dried at 110° C., contained 16.27 per cent of nitrogen. The filtrate from **4** was still further concentrated, and after cooling and adding a large amount of alcohol, gave a precipitate, "**5**," which, when treated as the others, weighed 4.21 grams and contained 6 per cent of nitrogen. The filtrate from **5** was highly concentrated and treated with absolute alcohol. The precipitate thus thrown down, "**6**," after treating with absolute alcohol, ether, absolute alcohol again, and drying over sulphuric acid, weighed 17.78 grams and contained 8.61 per cent of nitrogen.

To sum up: From the alcoholic extract, by concentrating and cooling three times, there resulted three preparations, viz:

1, of 15.5 grams, containing 13.92 per cent of nitrogen.

2, of 10.30 grams, containing 12.36 per cent of nitrogen.

3, of 6.82 grams, containing 10.37 per cent of nitrogen.

From the alcoholic washings of **1**, **2**, and **3**, by concentration and cooling was obtained preparation

4, of 14.62 grams, containing 16.27 per cent of nitrogen.

And by further concentration and addition of much strong alcohol,

5, of 4.21 grams, containing 6 per cent of nitrogen.

6, of 17.78 grams, containing 8.61 per cent of nitrogen.

The principal impurity recognized in these preparations was sugar, which was abundant in **5** and **6**.

These six preparations were examined separately.

1 was warmed with alcohol of 75 per cent, but was only partly soluble, and owing to its slimy nature, could not be filtered. Three volumes of strong alcohol were added, making the solvent equivalent to 2 liters of about 88 per cent alcohol. After heating to boiling and cooling, a little substance separated, which was filtered out, together with the undissolved portion. This precipitate and residue, "**1 A**," after treatment with absolute alcohol, ether, etc., as before described, weighed 3.68 grams and contained 14.57 per cent of nitrogen.

The filtrate from **1 A**, concentrated to one-third and cooled, deposited but little substance. Addition of an equal volume of water produced a precipitate. The liquid was poured off and the deposit treated with a large amount of absolute alcohol. The residue, "**1 B**," after drying, weighed 3.05 grams and contained 15.39 per cent of nitrogen. Water was added to the filtrate from **1 B**, but only a trifling precipitate resulted. The aqueous solution was then boiled, the coagulum filtered off, washed with absolute alcohol, and dried over sulphuric acid. This preparation, "**1 C**," weighed 2.45 grams and contained as follows:

Coagulated proteid directly extracted from ground oats by weak alcohol (**1 C**).

Carbon	52.66
Hydrogen	6.89
Nitrogen	16.32
Sulphur, Oxygen, Ash	24.13
	100.00

Carbon and hydrogen.—0.3120 gram, dried at 110° C., gave 0.6025 gram CO_2=52.66 per cent C and 0.1934 gram H_2O=6.89 per cent H.

Nitrogen (Kjeldahl method).—0.5624 gram, dried at 110° C., gave ammonia=10.75 cc. HCl (1 cc. HCl=0.00854 gram N)=16.32 per cent.

Ash could not be determined for want of material.

Nothing more could be obtained out of the filtrate from **1 C.**

2 and **3** were united and treated with 400 cc. of boiling alcohol of 0.9 sp. gr. A part dissolved to a deep-red solution. The residue was extracted again with hot dilute alcohol and treated in the same manner as the other preparations. Thus was obtained 9.05 grams of substance "**2** and **3 A**," containing 15.47 per cent of nitrogen.

This preparation was again treated, first with hot water and then with hot alcohol of 0.9 sp. gr., but only a little dissolved and the nitrogen content was unchanged.

The alcoholic filtrate from **2** and **3 A** was further examined, but only 2.3 grams of substance with 7.66 per cent of nitrogen were obtained. The long heating in very weak alcohol to which preparations **2** and **3** had been subjected had rendered a large share of the proteid insoluble, and it was therefore lost for further purification.

4 was treated with 500 cc. of alcohol of 0.9 sp. gr., in which a part was insoluble, "**4 A**." This was washed with alcohol and ether, dehydrated with absolute alcohol, and, after drying over sulphuric acid, weighed 8.9 grams. Its analysis follows:

Coagulated proteid directly extracted from ground oats by weak alcohol (**4 A**).

Carbon	53.09
Hydrogen	6.96
Nitrogen	16.56
Sulphur } Oxygen }	23.39
	100.00
Ash	.35

Ash.—0.5069 gram air-dried (=0.4555 dried at 110° C.) gave 0.0016 gram ash = .35 per cent.

Carbon and hydrogen.—0.4354 gram, dried at 110° C., gave 0.8445 gram CO_2=52.90 per cent C, and 0.2716 gram H_2O=6.91 per cent H.

Nitrogen (Dumas method).—0.5425 gram, dried at 110° C., gave 76.12 cc. gas at 9° C. (barometer 756.3 mm. at 9° C.)=16.76 per cent, less correction of 0.20=16.56 per cent N.

The alcoholic filtrate from **4 A** was concentrated to small volume, but as a slimy precipitate appeared, which could not be filtered, the solution was mixed with water. This did not cause the substance to separate in a manageable form, so the liquid was boiled, and after cooling the substance deposited as a gelatinous lump. After filtering, the deposit, "**4 B**," was treated with absolute alcohol and with ether and dried over sulphuric acid. It weighed 2.6 grams. Its analysis is subjoined:

Coagulated proteid directly extracted from ground oats by weak alcohol (**4 B**).

	I.	II.
Carbon	53.12	.....
Hydrogen	6.91	.....
Nitrogen	16.52	16.39
Sulphur } Oxygen } Ash }	23.45	.....
	100.00	

Ash.—Very little. Not determined for want of substance.

Carbon and hydrogen.—0.3145 gram, dried at 110° C., gave 0.6700 gram CO_2=53.12 per cent C, and 0.2143 gram H_2O=6.91 per cent H.

Nitrogen, I (Dumas method).—0.2633 gram, dried at 110° C., gave 37.93 cc. gas at 8° C., less correction of 0.7 cc. (barometer 756.3 mm. at 9° C.)=16.52 per cent N.

Nitrogen, II (Kjeldahl method).—0.2693 gram substance, dried at 110° C., gave ammonia=9.68 cc. HCl (1 cc. HCl=0.00854 gram N)=16.39 per cent.

The filtrate from **4 B** was evaporated to dryness and yielded one gram of substance containing 7.5 per cent of nitrogen.

6 evidently contained a large amount of sugar. It was first treated repeatedly with water, in which it formed a pasty lump. This was dehydrated with absolute alcohol, and when dried over sulphuric acid weighed 7.63 grams and contained 14.61 per cent of nitrogen="**6 A**."

6 A was then treated with 100 cc. of water, with which it formed a stringy lump, which, after having been thoroughly kneaded under water, assumed a semiliquid condition and could not be separated from the solution either by boiling or freezing. The solution, after concentrating on the water-bath to about 30 cc., was poured into 300 cc. of absolute alcohol. This threw down a curdy white precipitate, which, after treating with absolute alcohol and drying over sulphuric acid, weighed 6 grams and contained 15.67 per cent of nitrogen when dried at 110° C.="**6 A1**."

6 A1 was treated with 500 cc. of alcohol of 0.9 sp. gr. But little dissolved and the solution was too slimy to filter. The whole was then concentrated to one-third and cooled, but no separation took place which would allow of filtering or decanting the solution. The solution was, therefore, diluted with water and boiled. After cooling, a curdy precipitate settled out, leaving a turbid liquid. This liquid was decanted and poured into a large amount of absolute alcohol. On standing, a precipitate separated which, when treated with absolute alcohol and dried over sulphuric acid, weighed 0.455 gram and contained, when dried at 110° C., 16.40 per cent of nitrogen="**6 A2**."

There was thus obtained of the proteid soluble in alcohol a large number of fractional precipitations with different nitrogen content. It will be noticed, however, that five of these preparations have from 16.27 to 16.56 per cent of nitrogen. No preparations were obtained having a higher percentage of nitrogen, and none of the other preparations approximate to a constant nitrogen content.

4 had 16.27 per cent of nitrogen. When this was separated into two parts, one soluble in dilute alcohol—**4 B**—and the other insoluble—**4 A**—the two parts were found to contain the same proportion of nitrogen, and exactly agreed in content of carbon and hydrogen. This is what might be expected of a pure proteid, for some of these bodies become insoluble without change of composition, so far as can be detected by our methods of analysis. **1 C**, without correction for ash, has nearly the same composition as **4 A** and **4 B**; a correction would tend to bring it into closer agreement. The amount of substance, however, was insufficient for an ash determination.

As all the preparations analyzed thus far were the insoluble modification of the proteid, a new extract was prepared. Five pounds of freshly ground oats were boiled up with 10 liters of alcohol of 0.915 sp. gr. The extract was pressed out and added to another 5 pounds of oats and again heated to boiling. After filtering, a perfectly clear, deep, ruby-red solution was obtained. This was concentrated by distillation on the water-bath to about one-third its original volume. On cooling, a large amount of substance separated. This was thrown upon a filter, and after twenty-four hours about seven-eights of the solution had passed through. The filter, with its contents, was then boiled in 10 liters of 60 per cent alcohol, in a flask fitted with a reflux condenser, for four hours. The substance entirely dissolved to a clear, deep-red solution. The solution was then concentrated by distillation to about one-half, and cooled rapidly to 35° C., when it filtered readily. The precipitate formed a tough, jelly-like mass which did not adhere to the paper. It was boiled, as before, for several hours, with 10 liters of 60 per cent alcohol, until completely dissolved. The perfectly clear solution was concentrated to one-half its volume, during which operation a large part of the substance deposited on the interior of the flask as a thick leather-like coating. This coating readily separated from the glass in large pieces of a dark-brown color. On cooling the liquid, a finely-divided yellowish precipitate appeared which did not settle out on standing. The muddy liquid was poured off and the leathery deposit was minced and treated with absolute alcohol, in order, if possible, to dehydrate the substance and render it pulverizable for analysis, but as it remained forty-eight hours without change, the attempt was abandoned. The substance suspended in the muddy liquid was now caused to separate by adding alcohol. After filtering, washing first with strong, then with absolute alcohol, the precipitate was united to the portion which had been digested with absolute alcohol, and the whole then boiled in 2 liters

of 60 per cent alcohol in a flask fitted with a return condenser. After three hours' boiling, about one-half had dissolved. Two liters more of 60 per cent alcohol were then added and the boiling continued. Considerable proteid still remained in a gelatinous form on the sides of the flask. The solution was filtered off and 1200 cc. of absolute alcohol were poured on the residual substance. This caused the jelly to break up into coarse lumps, whereupon 800 cc. of water were added, making 2 liters of 60 per cent alcohol, and the boiling on the water bath was continued for several hours. Some of the substance dissolved, the liquid was filtered, and the insoluble residue was treated for many days with absolute alcohol. It was then ground to a fine powder while still moist with alcohol, extracted with ether, and dried over sulphuric acid. This preparation, "**7**," weighed 9.1 grams.

The alcoholic solution filtered from the insoluble portion was concentrated to one-half and filtered, while hot, from the large amount of substance which had separated. The latter resembled raw rubber in appearance and consistence, but not in elasticity. It was finely minced, and, after having been digested with absolute alcohol, was pulverized, treated again with absolute alcohol, washed with ether, and dried over sulphuric acid. This, "**8**," weighed 26 grams and was a light powder of yellowish color. Unlike all the other preparations extracted from the oats by weak alcohol which were analyzed, 8 was still largely "uncoagulated" and soluble in that reagent.

These two preparations were analyzed with the following results:

Coagulated proteid directly extracted from ground oats by weak alcohol (**7**).

	I.	II.	III.	I. Ash-free.
Carbon	52.98	.....	.....	53.10
Hydrogen	6.86	.....	.....	6.87
Nitrogen	16.34	16.41	16.39	16.39
Sulphur	.....	.....	.....	23.64
Oxygen	} .25	.....	.....	.....
Ash	}	.....	.....	.....
				100.00

Ash.—1.007 grams air-dried substance (=0.9291 gram, dried at 110° C.) gave 0.0023 gram ash =0.25 per cent.

Carbon and hydrogen.—0.5076 gram, dried at 110° C., gave 0.9860 gram CO_2= 52.98 per cent C, and 0.3131 gram H_2O = 6.86 per cent H.

Nitrogen, I (Dumas method).—0.5000 gram air-dried (= 0.4606 gram, dried at 110° C.) gave 64.1 cc. gas at 8° C. (barometer 750 mm. at 15° C.) = 16.54 per cent less 0.20 found in blank = 16.34 per cent N.

Nitrogen, II (Kjeldahl method).—0.5000 gram air-dried (= 0.4606 gram, dried at 110° C.) gave ammonia =8.85 cc. HCl (1 cc. HCl = .00854 gram N) = 16.41 per cent.

Nitrogen, III.—0.5000 gram air-dried (= 0.4611 gram, dried at 110° C.) gave ammonia = 8.85 cc. HCl = 16.39 per cent N.

Soluble proteid directly extracted from ground oats by weak alcohol (**8**).

	I.	II.	III.	IV.	I. Ash-free.
Carbon	52.92	.....	.....	.....	53.06
Hydrogen	6.93	.....	.....	.....	6.94
Nitrogen	16.33	16.33	16.45	16.54	16.38
Sulphur	2.25	2.24	.....	.....	2.26
Oxygen	.....	.....	.....	.....	21.36
Ash	.24	.....	.....	.....	.....
					100.00

Ash.—1.0045 grams air-dried (=0.9027 gram, dried at 110° C.) gave 0.0022 gram ash=0.24 per cent.

Carbon and hydrogen.—0.4821 gram, dried at 110° C., gave 0.9356 gram CO_2=52.92 per cent C, and 0.3003 gram H_2O=6.93 per cent H.

Nitrogen, I (*Dumas method*).—0.5000 gram air-dried (=0.4554 gram, dried at 110° C.) gave 63.1 cc. gas at 10° C. (barometer 759.5 mm. at 16° C.)=16.53 per cent, less corrections 0.20=16.33 per cent N.

Nitrogen, II.—0.5000 gram (=0.4490 gram, dried at 110° C.) gave 62.42 cc. gas at 14° C. (barometer 770.3 mm. at 17° C.)=16.53 per cent N.; corrected=16.33 per cent N.

Nitrogen, III. (*Kjeldahl method*).—0.5000 gram (=0.4490 gram, dried at 110° C.) gave ammonia =8.65 cc. HCl (1 cc. HCl=.00854 gram N)=16.45 per cent N.

Nitrogen, IV.—0.5000 gram (=0.4490 gram, dried at 110° C.) gave ammonia=8.70 cc. HCl= 16.54 per cent N.

Sulphur, I.—1.00 gram air-dried (=0.9107 gram, dried at 110° C.) gave 0.1850 gram $BaSO_4$, which, when fused with Na_2CO_3 and reprecipitated, gave 0.1495 gram $BaSO_4$=0.020532 gram S= 2.25 per cent.

Sulphur, II.—1.00 gram (=0.9107 gram, dried at 110° C.) gave 0.1575 gram $BaSO_4$, which, when fused with Na_2CO_3 and reprecipitated, gave 0.1469 gram $BaSO_4$=0.020175 gram S=2.21 per cent.

These analyses are observed to agree closely with each other, as well as with several of the preparations obtained under various conditions from the first extract already described, as is shown by the following table:—

Oat-proteid extracted by weak alcohol.

	Soluble.	Congulated.					
	S.	7.	1C.*	4 A.	4 B.*	1.	6A2.*
Carbon	53.06	53.10	52.66	53.09	53.12	.....	.....
Hydrogen	6.94	6.87	6.89	6.96	6.91	.....	.....
Nitrogen	16.38	16.39	16.32	16.56	16.52	16.27	16.40
Sulphur	2.26						
Oxygen	21.36	23.64	24.13	23.39	23.45	.....	.....
	100.00	100.00	100.00	100.00	100.00	.....	.....

*Not corrected for ash.

The figures given by Kreusler for the nitrogen of two precipitates from his first alcoholic extract are likewise in close agreement with the above, viz, 16.22 and 16.21 per cent. From his "oat-legumin" Kreusler also extracted by means of alcohol a substance with 16.38 per cent nitrogen.

It seems hardly probable that such concordant analyses could result from impure preparations or from a mixture of two or more proteids, especially in view of the varying conditions under which the preparations were obtained.

The very high content of sulphur is remarkable. No other analysis of a vegetable proteid approaches this amount. Ritthausen* found, indeed, in a single preparation from sesame presscake 2.36 per cent, but he attributed this high percentage to some foreign substance precipitated with the proteid. He afterwards† stated the percentage of sulphur as 1.25, and ascribed the high figure first obtained to calcium sulphate. Among the animal proteids besides *Keratin*, some forms of human *serum-albumin* contain 2.3 per cent of sulphur.‡

The fact that sulphur in my analyses is 0.60 per cent more than found by Kreusler in his gliadin indicates that his substance had undergone chemical change during the processes of preparation.

Ritthausen believes to have obtained from wheat gluten by extracting with alcohol three distinct proteids, to which he applies the names *fibrin*, *gliadin*, and *mucedin*, and he includes under one or the other of these terms all the proteids soluble in alcohol which he and Kreusler found in their extended study of the cereals. That portion of wheat gluten which is insoluble in alcohol Ritthausen denominated *gluten-casein*.

*Pflüger's Archiv. 21, 95 (1880). †J. prakt. Chem. 26, 444. ‡Starke; Jsb. thier. Chem. 11, 19.

On the authority of Ritthausen, his names and the composition attributed by him to these substances have passed into chemical literature, and have superseded the various designations and analyses of the older investigators.

The proteid of the oat which I have obtained, soluble in alcohol, differs essentially, however, in composition from all these preparations of Ritthausen and Kreusler. Kreusler's analysis of mucedin from barley grits alone fairly agrees with my results as respects carbon, hydrogen, and nitrogen, but the same chemist's analysis of mucedin from barley meal gives 0.84 per cent higher nitrogen than that from grits, and but 0.68 per cent sulphur.

In case of the other substances the discrepancies are still more decided. The properties and reactions given by Kreusler for the substance called by him *oat-gliadin* are true of the body just described, but these reactions mostly belong to proteids in general, or to the mucedin and fibrin of Ritthausen, and are not characteristic of any one body. Ritthausen states that on evaporating the alcohol solution of the gluten-fibrin prepared by him from wheat-gluten, a pellicle forms on the surface which renews itself as often as removed, and that neither mucedin nor gliadin shows this property. I have frequently observed the formation of films on evaporating solutions of the alcohol soluble proteid from oats. This body, however, can not be a mixture of Ritthausen's fibrin and gliadin, as its sulphur content so largely exceeds theirs.

2. EXTRACTION WITH ALCOHOL AFTER TREATMENT WITH WATER.

(Preparation 9.)

Five pounds of oats were treated with water as long as any proteid was dissolved. The residue was then twice extracted with alcohol and strongly pressed. The first alcoholic extract was evaporated so far as to remove nearly all the alcohol. On cooling, the solution became turbid, and after standing deposited a brown, slimy substance exceedingly soluble in dilute alcohol. The liquid was decanted and the precipitate dissolved in dilute alcohol. After evaporating off the alcohol and cooling, the substance separated as before; the aqueous solution was decanted and the slimy residue treated with ether, which extracted a fatty oil from this material and caused it to assume a more solid consistence. The substance was then treated with alcohol of 93 per cent, which dissolved a little and converted the remainder into a solid lump, so that it could be transferred to a flask and digested with ether. By the continued action of ether the viscid substance was transformed into a loose, yellowish powder. After standing under ether for twenty-four hours, the body was filtered out and dissolved in dilute alcohol. This alcoholic solution was filtered and evaporated on the water-bath to a small volume. After cooling, the solution was poured from the gummy substance adhering to the dish, which was washed with water and repeatedly digested with absolute alcohol. As long as the substance retained water, a little dissolved during treatment with alcohol. The residue became granular and brittle, and was easily reduced to a fine powder. When impregnated with absolute alcohol the mass rapidly absorbed moisture from the air and became soft and viscid.

After thorough dehydration with absolute alcohol the substance was rapidly filtered out and dried over sulphuric acid. It weighed 7.88 grams.

In testing the purity of this substance it was found to yield something to water. The whole preparation was, therefore, washed out completely with distilled water, and again treated with absolute alcohol and ether and dried over sulphuric acid. Analysis of this preparation (9) gave the following results:

Soluble proteid extracted by weak alcohol from ground oats after treating them with water (9).

	I.	II.
Carbon	53.64	.....
Hydrogen	6.88	.....
Nitrogen	15.70	15.36
Sulphur	1.75	.....
Oxygen	22.03	.....
	100.00	

Ash.—0.6007 gram air-dried left no ash.

Carbon and hydrogen.—0.5886 gram, dried at 110° C., gave 1.1579 grams CO_2=53.64 per cent C., and 0.3642 gram H_2O=6.88 per cent H.

Nitrogen, I (Dumas' method).—0.5000 gram air-dried (=0.4479 gram dried at 110° C.) gave 60.68 cc. gas at 8° C. (barometer 757 mm. at 12° C.) = 15.90 per cent N, less .20 for blank = 15.70 per cent.

Nitrogen, II (Kjeldahl method).—0.5000 gram air-dried (= 0.4479 gram dried at 110° C.) gave ammonia = 8.05 cc. HCl (1 cc. HCl = 0.00854 gram N) = 15.36 per cent.

Sulphur.—0.8958 gram, dried at 110° C., gave 0.1142 gram $BaSO_4$= 0.0157 gram = 1.75 per cent S.

3. EXTRACTION WITH ALCOHOL AFTER TREATMENT WITH SALT SOLUTION.

(Preparations 10 and 11.)

Five pounds of oats were repeatedly treated with 10 per cent solution of sodium chloride until nothing more was dissolved, and after pressing out as thoroughly as possible the residue was twice treated with alcohol of 0.912 sp. gr., being pressed out each time, and the extracts kept separate. The first and second alcohol-extracts were united, evaporated on the water bath until all alcohol had escaped, and the residue then cooled to 10° C. At this temperature the deposit formed brittle lumps, which, after decanting the solution, were treated with ether and absolute alcohol. The lumps were thus brought into a granular state, in which condition the substance was treated for some time with ether until all fat had been removed. It was then dissolved in hot dilute alcohol, filtered, and evaporated on the water bath to a small volume. On cooling the proteid separated in a mass on the bottom of the dish. The aqueous liquid was poured off, and the residue treated with absolute alcohol and ether, whereupon it became brittle and was easily ground to a fine powder. This powder was washed with water until it no longer gave with silver nitrate a reaction for chlorine. It was then treated with absolute alcohol and dried over sulphuric acid. In appearance and behavior it resembled in all respects the substance extracted by alcohol after the oats had been treated with water. When analyzed it was found to have the composition stated under 10.

The third alcoholic extract of the oats was treated in the same way, and the product obtained analyzed with the following results (11):

Soluble proteid extracted by weak alcohol from ground oats after treating them with salt solution (10 *and* 11).

	10.			11.	
	I.	II.	III.	I.	II.
Carbon	53.97			53.55	
Hydrogen	7.14			6.80	
Nitrogen	15.71	15.66	15.68	15.61	15.52
Sulphur	1.80			} 21.04	
Oxygen	21.38				
	100.00			100.00	
Ash	0.56			0.25	

DETAILS OF ANALYSES OF 10

Ash.—1 gram air-dried (= 0.9361 gram dried at 110° C.) gave 0.0053 gram ash = 0.56 per cent.

Carbon and hydrogen.—0.3443 gram, dried at 110° C., gave 0.6780 gram CO_2=53.70 per cent C., and 0.2200 gram H_2O=7.09 per cent H.

Nitrogen, I (Dumas method).—0.5000 gram air-dried (=0.4681 gram dried at 110° C.) gave 60.47 cc. gas at 8° C. (barometer 772 mm. at 8° C.)=15.80 per cent, less 0.20 for blank=15.60 per cent N.

Nitrogen, II (Kjeldahl method).—0.5000 gram air-dried (=0.4681 gram dried at 110° C.) gave ammonia=8.53 cc. HCl (1 cc. HCl=0.00854 gram N)=15.57 per cent N.

Nitrogen III.—0.5000 gram gave ammonia=8.55 cc. HCl=15.59 per cent N.

Sulphur.—1 gram air dried substance (=0.9361 gram at 110° C.) gave 0.1232 gram $BaSO_4$=0.0169 gram=1.80 per cent.

DETAILS OF ANALYSES OF 11

Ash.—0.8680 gram, dried at 110° C., gave 0.0022 gram ash=0.25 per cent.

Carbon and hydrogen.—0.3676 gram, dried at 110° C., gave 0.7490 gram CO_2=53.42 per cent C., and 0.2242 gram H_2O=6.78 per cent H.

Nitrogen, I (Kjeldahl method).—0.5000 gram (=0.4715 gram dried at 110° C.) gave ammonia=8.60 cc. HCl (1 cc. HCl=0.00854 gram N)=15.59 per cent N.

Nitrogen II.—0.5000 gram (=0.4715 gram dried at 110° C.) gave ammonia=8.55 cc. HCl=15.49 per cent N.

4. EXTRACTION WITH ALCOHOL AFTER TREATMENT WITH WATER AND SALT-SOLUTION.

(Preparation 12.)

Five pounds of oats were extracted with water, and then with 10 per cent salt-solution as long as anything was removed. The residue was twice digested with alcohol of 0.9 sp. gr., the two alcohol extracts were united and concentrated to a small volume on the water-bath. After cooling, the substance which deposited was filtered out and dissolved in dilute alcohol. The filtered solution was evaporated until nearly all the alcohol was expelled, and finally poured into cold water. The abundant precipitate thus produced settled rapidly, forming a pasty mass on the bottom of the dish, from which the water could be completely decanted. By treatment with ether and absolute alcohol the substance was rendered dry and brittle, and was easily ground to a yellowish powder. This was transferred to a flask and digested for twenty-four hours with a mixture of absolute alcohol and ether, then washed with ether to remove the alcohol, and dried in the air. The product weighed 12 grams. After dissolving this preparation in dilute alcohol and evaporating to a small volume on the water-bath, the concentrated solution was poured into a liter of cold distilled water. The substance thus precipitated was washed by decantation with distilled water until all chlorides had been removed, then treated with absolute alcohol and ether and dried over sulphuric acid. This preparation was found to have the following composition:

Soluble proteid extracted by weak alcohol from ground oats after treating them with water and with salt-solution (12).

	I.	II.
Carbon	53.63	.....
Hydrogen	7.16	.....
Nitrogen	15.83	15.86
Sulphur	1.74	.....
Oxygen	21.64	.....
	100.00	
Ash	0.11	

Ash.—0.7593 gram, dried at 110° C., gave 0.0008 gram ash=0.11 per cent.

Carbon and hydrogen.—0.2850 gram, dried at 110° C., gave 0.5595 gram CO_2=53.58 per cent C., and 0.1836 gram H_2O=7.15 per cent H.

Nitrogen, I (Dumas method).—0.4168 gram, dried at 110° C., gave 56.95 cc. N at 18° C. (barometer 764.5 mm. at 22° C.)=15.81 per cent.

Nitrogen, II (Kjeldahl method).—1.0183 grams, dried at 110° C., gave ammonia=19.63 cc. HCl (1 cc. HCl=0.00822 gram N)=15.84 per cent.

Sulphur.—0.9682 gram, dried at 110° C., gave 0.1218 gram $BaSO_4$=0.01673 gram S=1.74 per cent.

RECAPITULATION.

The following statement brings together the analyses of the four preparations last described:

	Proteid extracted from oats by weak alcohol after treatment of the meal with—				
	Water.	Salt-solution.		Water and salt-solution.	Average.
	9.	10.	11.	12.	
Carbon	53.64	53.97	53.55	53.63	53.70
Hydrogen	6.88	7.14	6.80	7.16	7.00
Nitrogen	15.70	15.71	15.61	15.83	15.71
Sulphur	1.75	1.80	24.04	1.74	1.76
Oxygen	22.03	21.38		21.64	21.83
	100.00	100.00	100.00	100.00	100.00

When the above analyses are compared, as below, with those of the preparations obtained without previous treatment of the oats with water or salt-solution, it is evident that we have in hand two quite different and distinct substances, neither of which agrees in composition with Krensler's *oat-gliadin*.

	Proteid extracted from oats by weak alcohol—	
	Without action of water or salt-solution.	After action of water or salt-solution
	8.	Average.
Carbon	53.06	53.70
Hydrogen	6.94	7.00
Nitrogen	16.38	15.71
Sulphur	2.26	1.76
Oxygen	21.36	21.83
	100.00	100.00

The differences in behavior of the two substances are much more marked than those of composition. The body extracted by alcohol without the previous treatment with water becomes insoluble in alcohol with great readiness, and, after having been dissolved and precipitated a few times, is again dissolved very slowly and only in a large amount of hot alcohol of 0.9 sp. gr. When wet with absolute alcohol it can be exposed to moist air without becoming gummy.

On the other hand, the body extracted by alcohol after the action of water or 10 per cent salt-solution shows no tendency to become insoluble, even after long heating with very dilute alcohol. It is freely soluble even in cold alcohol of 0.9 sp. gr., and, when wet with absolute alcohol, immediately attracts moisture from the air, becoming sticky and viscid. In appearance the two bodies do not materially differ, both being light, yellowish powders, when prepared as described.

Both these substances are soluble in dilute acids and alkalies to solutions from which on neutralization they precipitate, retaining their solubility in dilute alcohol.

The fact that weak alcohol acts as a solvent for these bodies, which are insoluble in either pure (absolute) alcohol or pure water, is doubtless due to the formation of hydrates that, while insoluble in water, are soluble in alcohol, but that can not exist in strong alcohol, being thereby dehydrated.

The proteid whose composition is expressed by analysis 8 was first obtained by Norton, who extracted ground oats directly with hot alcohol, distilled the solution carefully to dryness, dissolved out the oil by ether and the salts and sugar by water. Norton designated this body *Glutin*, and considered it "analogous to the glutin of wheat;" he states that the preparation which he thus

separated and weighed was no longer soluble in alcohol, but he did not attempt any further investigation of its properties or composition.*

Von Bibra, who found in oats 3 per cent of *Plant-gelatin* (Pflanzenleim), does not describe its mode of preparation, but states that it contained 15.6 per cent of nitrogen.

Kreusler indeed extracted crushed oats directly by 80 per cent alcohol, and in his first preparations found 16.22 and 16.21 per cent of nitrogen; but the substance, from whose analysis he decided upon the composition of *Oat gliadin*, had been "purified" by dissolving in acetic acid and precipitating by potash solution, and, according to his results, contained 1.3 per cent more nitrogen, 0.65 per cent more hydrogen, and 0.6 per cent less sulphur than exist in the proteid soluble in alcohol which I have analyzed.

IV.—Proteids extracted by Water.

The water extract of freshly ground oats has a strong acid reaction. The acidity measured by litmus is much less than by phenol-phthalein. One hundred cc. of an aqueous extract became neutral to delicate litmus paper after adding ten cc. of two-tenths per cent potash solution, and five cc. more of the same solution were added before phenol-phthalien showed an alkaline reaction. On neutralizing the water extract of oats with two-tenths per cent potash, using phenol-phthalein as an indicator, a considerable precipitate appeared, which was soluble in the slightest excess either of alkali or of the acid contained in the extract. This neutralization precipitate indicates the presence of so-called *acid albumin*. The perfectly neutralized solution when heated to boiling remained clear. On adding 10 per cent of sodium chloride to the neutralized and filtered liquid, a considerable precipitate formed upon boiling, as well as on the addition of acetic acid. When the unneutralized extract was boiled and the resulting coagulum filtered off, neither sodium chloride nor acetic acid gave a precipitate in the filtrate on boiling. The substance remaining in solution after neutralization, but precipitated by boiling, in the presence of sodium chloride or on the addition of acetic acid, is a *globulin*, to be described later.

The water extract, when heated slowly in a test-tube immersed in a beaker of water which in turn was set in a larger beaker of water, showed a turbidity first at 57° C., and minute flocks appeared at 64° C. Heated to 70° and filtered, the solution remained clear until raised to boiling, when a slight precipitate formed. When 10 per cent of sodium chloride was added to the extract, the turbidity appeared at 44° C., and flocks formed at 64° C.

Five pounds of oats were treated with 6 liters of water for twenty-four hours, pressed out, and extracted a second time for twenty-four hours with the same amount of water. The aqueous extract reacted strongly acid to litmus, but was not neutralized, as the possible action of the acid was kept in mind, and the immediate object in view was to find what substances were extracted by the use of water alone. The two extracts were united, saturated with commercial ammonium sulphate and the precipitate thereby resulting was filtered off, and scraped from the filter, the paper was washed out with water, the solution being added to the dark olive-green precipitate which partly dissolved to a brown solution. After the solution and suspended precipitate had dialysed for fourteen days in a stream of running water, thymol being added to prevent decomposition, the solution was found to be nearly free from sulphate. The contents of the dialyser were then filtered from a dark green precipitate which had not dissolved on removing the salts. The filtrate was found not to coagulate on boiling, and was evaporated to dryness on the water-bath, leaving a brown residue which weighed between 1 and 2 grams and gave the following reactions:

With sulphate of copper and caustic potash it yielded a red-purple color, of a bluer tint than given by peptones or proteose, which increased on standing. Millon's reagent with the aqueous solution gave a strong reaction. Alcohol of 0.9 sp. gr. dissolved a portion which, after removal of the alcohol, was readily soluble in water and reacted for proteids with Millon's reagent and the biuret test. After evaporation of the alcohol on the water bath, the substance was but partially soluble in water. The alcoholic solution was precipitated by adding stronger alcohol. Fehling's solution gave no reaction until after heating with dilute acid, when a very slight precipitate of cuprous oxide appeared. Very dilute hydrochloric acid gave no precipitate in the solution, and stronger acid

*Am. J. Sci. [2] 3, 229.

made a slight turbidity. These reactions indicate presence of a *proteose* and absence of true *albumin*.

The substance remaining after dialyzing the ammonium-sulphate precipitate was treated with 10 per cent brine of sodium chloride; the resulting solution was filtered off and dialyzed till free from chlorides. Nothing precipitated on removal of the salt, the proteid being soluble in water. This fact shows that no globulin had been extracted from the substance which separated on dialysis of the aqueous extract, the globulin having been converted into an insoluble form. This dialyzed solution was not coagulated by boiling, and was therefore evaporated to dryness on the water bath. The residue, weighing about 1 gram, was not quite completely soluble in water. As much as possible was dissolved in a small amount of water, and filtered from a slight residue. The solution was colored deep yellow-brown, contained a trace of chlorides, gave no precipitate with hydrochloric acid, either very dilute or strong. No biuret reaction was discernible in the colored solution, which gave the proteid coloration with Millon's test, and did not reduce Fehling's solution before treatment with acids. On long standing, after heating with hydrochloric acid, a little cuprous oxide separated. Evidently this substance is the same (*proteose?*) as that obtained from the solution remaining after dialyzing the ammonium sulphate precipitate.

The substance remaining after dialysis and insoluble both in water and in 10 per cent brine was found to be partly taken up in one-half per cent sodium carbonate solution and in dilute hydrochloric acid, being the result of the alteration of globulin, which had passed into solution by means of the salts derived from the oats. The neutralization precipitate from sodium carbonate solution was slightly soluble in 10 per cent brine of sodium chloride. The fact that the ammonium sulphate used in this work was crude and had a slightly acid reaction and a bluish tint, to which the green color of the precipitate was due, may throw doubt on the results here recorded, but as they were mostly corroborated on repeating the trials with pure and neutral ammonium sulphate, I have given them in detail.

The results of a second examination of proteids soluble in water here follow: Five pounds of oats were treated with 7 liters of water for forty-eight hours, thrown on a sieve, the residue pressed out and treated for a short time with 6 liters more of water. The two extracts were united and allowed to settle, when the nearly clear liquid was syphoned off and saturated with pure ammonium sulphate. After the white precipitate thus produced had stood over night, it separated in large flocks from the liquid, and was filtered out and dissolved mostly in 10 per cent sodium chloride brine, filtered, and the clear solution dialyzed. The precipitate was not completely soluble in 10 per cent sodium chloride brine nor in water—in these respects resembling the precipitate obtained from the first extract after it had been dialyzed. The clear, filtered solution in 10 per cent sodium chloride brine, on standing, slowly deposited a part of the dissolved substance. The solution, with the precipitate which had formed, was dialyzed until free from salts, and the solution after filtering again was evaporated to dryness on the water bath, leaving a residue of 1.11 grams. The precipitate filtered out was quite small in amount. The total proteid obtained by saturating with ammonium sulphate was less than that got in the first extraction, probably because the oats were allowed to stand twice as long in contact with water as in the case of the first extract, for it was found that the clear, filtered extract of the ammonium sulphate precipitate in 10 per cent sodium chloride brine, on standing, deposited the dissolved substance, so that before the conclusion of the dialysis nearly all the proteid originally soluble in water had lost its solubility.

Weyl states that water converts vegetable globulins into "albuminates;" that is, into forms no longer soluble in salt solutions, but soluble in 1 per cent sodium carbonate solution or 0.8 per cent hydrochloric acid, and that a long-continued action of water finally converts the albuminates thus produced into modifications that are no longer soluble in 1 per cent sodium carbonate solution or 0.8 per cent hydrochloric acid. They are then not to be distinguished from "coagulated proteids." This latter change he has observed only for the globulins of peas and oats.

Transformations of this character occurred in the two extracts just described. In the first, after dialysis, the residue insoluble in 10 per cent sodium chloride brine was partly soluble in one-half per cent sodium carbonate solution, and in the second a body was formed insoluble in water and in 10 per cent sodium chloride brine, but soluble in one-half per cent sodium carbonate solution.

To sum up, we have in the aqueous extract of the oat kernel the following bodies:

1. An *acid albumin*, precipitated by exact neutralization of the extract.

2. One or more *globulins*, precipitated from the neutralized extract by sodium chloride and acetic acid; also precipitated by saturation with ammonium sulphate; remaining insoluble in water on dialysis, being, as it would appear, by the action of the water converted into an "alkali albuminate."

3. A *proteose*, remaining in solution after dialysis of the ammonium-sulphate precipitate. This body exists also in the dialyzed solution of the ammonium sulphate precipitate from the sodium-chloride extract.

V.—Proteids Extracted by Cold Sodium Chloride Solution.

1. DIRECT EXTRACTION WITH SALT SOLUTION.

(Preparations 13 and 14.)

Freshly-ground oats, extracted with 10 per cent brine of sodium chloride* at 15° to 20°, gave a brown solution which, when filtered clear, coagulated as follows: Heated to 42° C., a very slight turbidity formed, which increased very slowly up to 57°, at which temperature it was still slight. Above this point it increased more rapidly, at 61° the solution being opaque; at 72° flocks formed. Heated at 73° some minutes and then filtered, the filtrate became turbid again at 70°, the turbidity increasing somewhat up to 87°; from 87° to 90° the increase was more rapid, but the amount separated at 90° was small. The solution heated to 90° and filtered, became turbid again at 85°, with little change up to 97°. Heated to boiling for a short time and filtered, the filtrate gave abundant precipitate with acetic acid.

Dilute acetic or hydrochloric acid yields a large precipitate in the brine extract, which is insoluble in a slight excess of the acid. Either saturation with sodium chloride or dilution with water throws down a copious precipitate. The precipitate produced by water, on standing in the dilute salt solution two days, becomes insoluble in 10 per cent sodium chloride brine and in one-half per cent sodium carbonate solution.

Saturation with ammonium sulphate completely precipitates the proteids from this solution in 10 per cent sodium chloride brine.

Five pounds of freshly ground oats were treated twice with 10 per cent sodium chloride solution, and after filtering, the extract was saturated with commercial—but perfectly neutral—ammonium sulphate, which gave a dark greenish color to the extracted substances without otherwise affecting their properties. The bulky precipitate was filtered off, suspended in water and dialyzed fourteen days, until nearly free from sulphates.

A heavy precipitate remained undissolved. This was filtered out, and the filtrate and precipitate were separately examined.

Filtrate.—When heated very slowly in a test-tube, in the manner previously described, the solution was found to become turbid at 58° C.; at 70° C. flocks were formed. Heated to boiling and filtered, the filtrate gave a strong reaction with Millon's reagent. The entire solution was therefore concentrated to a small volume at 40° C., and dialyzed until all salts were removed. The coagulation point of the solution was again taken and found to be the same as before; turbidity at 58° C.; flocks at 73° C. The solution was strongly colored, appearing almost black by reflected light, and by transmitted light a greenish brown. With sulphate of copper and caustic potash and with Millon's reagent it gave good reactions; was not affected by very dilute hydrochloric acid, but was precipitated by stronger acid in the cold. Fehling's solution suffered no reduction, either before or after the action of acid. This solution was then evaporated on a plate below 50° C., and yielded about 6 grams of a very brittle, greenish-black, shining substance, very soluble in water, from which alcohol of 0.9 sp. gr. dissolved some proteid.

It is seen that when oats are extracted with 10 per cent sodium chloride solution, a substance soluble in water and coagulating at 58° to 73° C. is formed, which does not exist in the oats originally, for the aqueous extract, when treated in the same way, yields no substance coagulable even upon boiling.

*The sodium chloride employed was the "Diamond Crystal Table Salt," Eureka Salt Company, New York, which is "remarkably free from impurities."

The amount of this coagulable proteid, which has the properties characteristic of an *albumin*, was too small for analysis (0.5 gram from 2¼ kilograms of oats), but its importance in a study of these bodies is great, for Weyl has undertaken to classify the vegetable proteids after the manner now commonly adopted for those of animal origin, and has stated that the extracts of oats and other seeds in 10 per cent sodium chloride solution coagulate at 55° to 60° C., and consequently contain a *myosin*, since the myosin from animal muscle coagulates under these conditions at this temperature. He also states that besides myosin, *vitellin* exists in these seeds, as shown by filtering out the coagulum formed at 60° C. and heating the solution gradually to 75°, when a second coagulation takes place.

The proteid soluble in salt solutions, to be described further on, was found, when dissolved in a 10 per cent sodium chloride solution, to become turbid at 81° C. and to form flocks at 97°. This, then, has a coagulation point not far from that of vitellin, but it differs from that substance in being readily precipitated by sodium chloride even before saturation.

It is seen from the experiments above described that the presence of a very little coagulable substance may be highly misleading, and gives no certain basis for classifying or identifying the vegetable proteids, unless each body is separated from all the others and examined in detail by itself. Weyl did not attempt this, except for one preparation from the Brazil nut (*Bertholletia*), and therefore his conclusions based on coagulation points need further study before they can be accepted.

Precipitate.—The precipitate from the dialyzer, filtered out of the solution just considered, was treated with 10 per cent sodium chloride solution. A part of the substance which did not dissolve was filtered out, and the clear filtrate dialyzed till free from chlorides, when the proteid was found to be precipitated. This precipitate was filtered out, washed with water, absolute alcohol and ether, and dried over sulphuric acid.

The *globulin* thus obtained, "13," had the following properties:

In 10 per cent brine of sodium chloride it dissolved readily to a clear solution. Addition of an equal volume of water to this solution produced a copious precipitate. Addition of sodium chloride gave a large precipitate even before saturation. When the solution was diluted till turbid, the turbidity disappeared on warming gently.

Very dilute acetic or hydrochloric acid dissolved the substance readily when salts were not present. The addition of more acid gave no precipitate. Addition of a *very* little sodium chloride to a solution of the substance in very dilute acid made a slight precipitate; the addition of more sodium chloride threw down an abundant curdy precipitate. The more acid present, the more salt solution was required to produce a precipitate, and the more salt solution present, the less the amount of acid required for precipitation.

Dilute solution of citric acid in water (1 : 2000) gave results like acetic acid and dissolved the substance readily to a solution which was *not* coagulated on boiling.

From solution of the substance in 10 per cent brine, hydrochloric acid throws down a precipitate which is wholly insoluble even in strong solution of sodium carbonate (the filtrate giving no reaction with sulphate of copper and caustic potash), and is also insoluble in an excess of dilute acid. Acetic acid, on the other hand, gives a precipitate which, at first, is readily soluble in *very* dilute sodium carbonate, but the solution, on standing, becomes turbid.

Hydrochloric acid, in the presence of salt, converts this proteid into a "coagulated proteid;" acetic and citric acids transform it into an "albuminate."

The preparation gave the usual reactions with Millon's reagent, with cupric sulphate and potash, and with nitric acid. The solution in 10 per cent brine of sodium chloride on heating became turbid at 81° C., and at 97° C. the formation of flocks occurred. The same solution allowed to stand at summer temperature for more than a month showed no signs of turbidity, decomposition being prevented by adding from time to time a drop of a 20 per cent alcoholic solution of thymol. The composition of this globulin is here given:

Oat globulin.—First direct extraction with 10 per cent salt solution (13).

	I	II	III	Ash-free
Carbon	52.23	52.22		52.32
Hydrogen	7.15	6.99		7.10
Nitrogen	16.92	17.07	16.90	16.95
Sulphur	0.88			0.88
Oxygen				22.66
Ash	0.20			
				100.00

Ash.—0.7937 gram gave 0.0015 gram ash=0.20 per cent.

Carbon and hydrogen, I.—0.3561 gram gave 0.6822 gram CO_2=52.23 per cent C, and 0.2300 gram H_2O=7.15 per cent H.

Carbon and hydrogen, II.—0.4584 gram gave 0.8778 gram CO_2=52.22 per cent C, and 0.2883 gram H_2O=6.99 per cent H.

Nitrogen, I (Dumas method).—0.6225 gram gave 90.85 cc. nitrogen at 18° C. (barometer 765.5 mm. at 22° C.)=16.92 per cent N.

Nitrogen, II (Kjeldahl method).—0.5760 gram gave ammonia=11.95 cc. HCl (1 cc.=0.00822 gram N)=17.07 per cent N.

Nitrogen, III.—1.0476 gram gave ammonia=21.54 cc. HCl=16.90 per cent N.

Sulphur.—0.8022 gram gave 0.0513 gram $BaSO_4$=0.00705 gram S=0.88 per cent S.

A second preparation of globulin was as follows: Five pounds of ground oats were digested with 8 liters of 10 per cent sodium chloride solution for forty-eight hours, and pressed out. The residue was again subjected to the same treatment. The two extracts were united, filtered, the clear filtrate saturated with pure ammonium sulphate, and the precipitate thus produced was filtered off. This precipitate was found to be completely soluble in 10 per cent salt solution, save a slight turbidity, which was readily cleared up by very dilute sodium carbonate solution. It was therefore removed from the filter, suspended in water, and dialyzed for eleven days, whereby the salts were nearly all removed. The precipitate was filtered off, and the filtrate and precipitate were separately examined.

Filtrate.—The clear brown filtrate was evaporated to dryness at 50°, leaving an amber-brown instead of a greenish-black residue, as was obtained from the first salt extract.

The properties of this residue agreed exactly with those from the first salt extract, the difference in color being due to impurities in the ammonium sulphate used in saturating the first extract.

Precipitate.—The precipitate in the dialyzer was found to remain almost entirely soluble in salt solution, the trifling residue not taken up by that solvent yielded to dilute sodium carbonate, and when this solution was neutralized with a slight excess of acetic acid the separated substance dissolved in solution of common salt.

The dialyzed precipitate was therefore filtered, washed by decantation with water, alcohol, ether, and absolute alcohol, and dried over sulphuric acid. This body had all the properties of the one similarly prepared and already described (13). Twenty grams of substance were thus obtained, and by extracting the oat residue with 10 per cent sodium chloride solution, until no more proteid was taken up, and proceeding as just detailed, ten grams more of globulin were secured. The yield was accordingly 1.3 per cent of the air-dried oats. The analyses of this preparation here follow:

Oat globulin.—Second direct extraction with 10 per cent salt solution (14).

	I.	II.	III.	I. Ash-free.
Carbon	52.28	52.33	.....	52.32
Hydrogen	7.23	7.17	.....	7.24
Nitrogen	16.78	16.90	17.01	16.81
Sulphur	0.89	.....	.....	0.89
Oxygen	.....	.....	.....	22.69
Ash	0.21	.....	.....	.....
				100.00

Ash.—0.8060 gram gave 0.0017 gram ash=0.21 per cent.

Carbon and hydrogen, I.—0.2894 gram gave 0.5545 gram CO_2=52.28 per cent C, and 0.1883 gram H_2O=7.23 per cent H.

Carbon and hydrogen, II.—0.2190 gram gave 0.4200 gram CO_2=52.33 per cent C, and 0.1412 gram H_2O=7.17 per cent H.

Nitrogen I (Dumas method).—0.5314 gram gave 77.1 cc. nitrogen at 18° C. (barometer 763.5 mm. at 22° C.)=16.78 per cent N.

Nitrogen II (Kjeldahl method).—0.4732 gram gave ammonia=9.73 cc. HCl (1 cc.=0.00822 gram nitrogen)=16.90 per cent N.

Nitrogen III.—0.9973 gram gave ammonia=20.64 cc. HCl=17.01 per cent N.

Sulphur.—0.8400 gram gave 0.0547 gram $BaSO_4$=0.007513 gram S=0.89 per cent S.

2. EXTRACTION WITH SALT SOLUTION AFTER TREATMENT WITH ALCOHOL.

(Preparation 15.)

Since digestion of oats first with water or with salt solution altered the proteid soluble in alcohol, it was thought possible that by preliminary treatment with alcohol a body might be obtained soluble in salt solution and yet different from the one extracted directly by that solvent.

To test this hypothesis, 3 pounds of fine ground oats were three times extracted, in the cold, with 6 liters of alcohol of 0.9 sp. gr. After pressing out as thoroughly as possible, the residue was treated three times with 10 per cent sodium-chloride solution, the solvent each time being allowed to stand in contact with the oats for twenty-four hours. The first and second extracts were united, filtered, and saturated with sodium chloride. The precipitate was filtered out and found to be but partly soluble in 10 per cent brine. It was therefore dissolved in solution of sodium carbonate of one-fourth per cent, and the filtered liquor was exactly neutralized with acetic acid, which separated the proteid as a white precipitate. After washing thoroughly, by decantation with distilled water, with dilute alcohol, with ether, and finally with absolute alcohol, the substance was dried over sulphuric acid. As it weighed only 2.1 grams, the greater part of the proteid in the oats, soluble in salt solution, had evidently been converted into an "albuminate."

Oat globulin extracted by 10 per cent salt solution after treatment with alcohol, dissolved in one-fourth per cent sodium-carbonate solution and precipitated by acetic acid (15).

		Ash-free.
Carbon	52.39	52.48
Hydrogen	6.93	6.94
Nitrogen	16.82	16.85
Sulphur	0.57	0.57
Oxygen	.....	23.16
Ash	0.17	.....
		100.00

Ash.—0.3773 gram gave 0.0066 gram ash = 0.17 per cent.

Carbon and hydrogen.—0.3187 gram gave 0.6122 gram CO_2 = 52.39 per cent C, and 0.1993 gram H_2O = 6.93 per cent H.

Nitrogen (Dumas method).—0.3220 gram gave 47.17 cc. nitrogen at 18° C. (barometer 759.3 mm. at 28° C.) = 16.82 per cent N.

Sulphur.—0.7435 gram gave 0.0301 $BaSO_4$ = 0.004216 gram S = 0.57 per cent S.

VI.—Proteids Extracted by Weak Alkali Solutions.

1. EXTRACTION BY TWO-TENTHS PER CENT POTASH SOLUTION AFTER TREATMENT OF THE GROUND OATS WITH ALCOHOL.

(Preparation 16).

Another extraction was made in nearly the same manner as that employed by Kreusler in preparing his "oat-legumin:" Five pounds of freshly ground oats were treated in the cold with alcohol of 0.9 sp. gr. as long as any proteid was removed. The residue was digested for some time with 7 liters of two tenths per cent potash solution. The whole was then thrown on a sieve and the turbid percolate allowed to stand for twenty-four hours.

The dark-colored solution was siphoned off, let stand another day, decanted from the slight sediment, and then precipitated with very dilute acetic acid. After a day the substance had so far settled that about two-thirds of the liquid could be decanted. To the remainder alcohol was added until the solution had a sp. gr. of 0.93. On further standing the precipitate deposited and was transferred to a filter. It was washed with stronger alcohol, removed from the paper, and dissolved again in two-tenths per cent potash solution. A turbid liquid resulted which could not be filtered until a little sodium chloride had been added, which precipitated some of the dissolved proteid. The precipitate was soluble both in additional potash solution and in brine. More salt was therefore added; the nearly clear solution was then filtered, which process lasted for about a week. Decomposition was entirely prevented by the use of thymol. The filtrate obtained each day was precipitated with dilute acetic acid; the precipitate was washed on a filter with water, then with dilute and afterwards with strong alcohol, and was finally transferred to a flask filled with absolute alcohol. When the filtration was completed and the united precipitates had been digested with absolute alcohol, they were treated with ether and again with absolute alcohol, and lastly dried over sulphuric acid, yielding preparation "16."

Oat proteid extracted by two-tenths per cent potash solution after treatment of the ground oats with alcohol (16).

	I.	II.	III.	I. Ash-free.
Carbon	52.11	52.18	.....	52.45
Hydrogen	6.87	6.74	.....	6.92
Nitrogen	16.52	16.18	16.40	16.63
Oxygen	.....	.....	.....	23.19
Sulphur	0.81	.....	.....	0.81
Ash	0.66	.....	.....	.....
				100.00

Ash.—0.7373 gram gave 0.0049 gram ash = 0.66 per cent.

Carbon and hydrogen, I.—0.3666 gram gave 0.7005 gram CO_2 = 52.11 per cent C, and 0.2265 gram H_2O = 6.87 per cent H.

Carbon and hydrogen, II.—0.4523 gram gave 0.8651 gram of CO_2 = 52.18 per cent C, and 0.2746 gram H_2O = 6.74 per cent H.

Nitrogen, I (Dumas method).—0.3577 gram gave 51.44 cc. nitrogen at 18° C. (barometer 758.7 mm. at 22° C.) = 16.52 per cent N.

Nitrogen, II (Kjeldahl method).—0.5037 gram gave ammonia = 10.1 cc. HCl (1 cc. HCl = 0.00822 gram N) = 16.48 per cent N.

Nitrogen, III.—1.0412 gram gave ammonia = 20.77 cc. HCl = 16.40 per cent N.

Sulphur.—0.8670 gram gave 0.0510 gram $BaSO_4$ = 0.0070 gram S = 0.81 per cent S.

For comparison the analyses of the last four preparations are here stated together:

	13.	14.	15.	16.
Carbon	52.32	52.37	52.48	52.45
Hydrogen	7.19	7.24	6.94	6.92
Nitrogen	16.95	16.81	16.85	16.63
Sulphur	0.88	0.89	0.57	0.81
Oxygen	22.66	22.69	23.16	23.19
	100.00	100.00	100.00	100.00

13 and **14**, extracted directly by 10 per cent salt solution.

15, extracted by 10 per cent salt solution after treating the ground oats with alcohol, then dissolved in one-fourth per cent sodium carbonate solution and precipitated by acetic acid.

16, extracted by two-tenths per cent potash solution after completely exhausting the ground oats with alcohol.

The four preparations agree in composition so closely that it is fair to assume that they were pure and that the analyses correctly represent the composition of one and the same proteid.

Of the above analyses, **13** and **14** represent the composition of oat-globulin as extracted by 10 per cent solution of the pure sodium chloride and still soluble in that menstruum, while **15** and **16** represent the insoluble or "albuminate" modification of the same proteid.

Analysis of **15** indicates that the globulin is not essentially changed in composition by being dissolved in weak sodium carbonate solution and precipitated therefrom by dilute acid.*

Since all proteids, except the coagulated, are soluble in weak alkali, the analysis of **16**, made on a substance extracted by two-tenths per cent potash solution, may be taken to exhibit the composition of whatever uncoagulated proteids remain in the oat after the direct extraction with weak alcohol. The close agreement of the analysis of **16** with the other analyses leads to the conclusion that the oat proteids which are not extracted by weak alcohol mainly consist of either the globulin soluble in salt solution or its "albuminate" modification, or else of a proteid from which these are derived under the influence of the solvents employed in their preparation.

The amount of these preparations obtained in a form suitable for analysis was a very small fraction of the total proteid contained in the oats. This was probably due to the conversion of the globulin into an "albuminate" or a "coagulated proteid."

The exact cause of this change has not been ascertained. To test the hypothesis that it might be due to the action of an acid or acid salt contained in the oats, 100 grams of the freshly ground grain were treated with 800 cc. of two-tenths per cent potash solution. The resulting mixture was neutral to litmus and did not redden phenol-phthalein. Eighty grams of sodium chloride were then added, and the solution, after standing some time, was filtered. Very little proteid was thus extracted. In another trial 10 per cent solution of sodium chloride mixed with two-tenths per cent of sodium carbonate extracted but a small part of the proteids.

One hundred grams of oats treated with two-tenths per cent solution of sodium carbonate gave an extract containing much proteid, which on addition of a little sodium chloride yielded an abundant precipitate. Neutralizing the sodium carbonate extract gave a precipitate which was insoluble in sodium chloride solution.

These experiments indicate that the insolubility of the greater part of the oat proteids in 10 per cent brine is not due to the presence of an acid or acid salt.

Weyl has stated that when wheat flour is extracted with sodium chloride solution, the residue yields no gluten on kneading with water, and he considers that the gluten does not preëxist in the wheat, but is a product of ferment action. It was thought that if a ferment occasioned alteration of oat proteids, its effect might perhaps be prevented by treating the ground oats with a sodium chloride solution heated to 75° C., so that all the soluble proteids coagulable below that temperature would be rendered insoluble and inoperative as ferments. The globulin coagulating at 80° C. ought not to be affected by this treatment. Experiments made to prove this view did

*The low figure for sulphur in 15 is accidental, some loss having been incurred in oxidizing the substance by fusion with alkali nitrate and carbonate. The determination could not be repeated for lack of material.

not result in the extraction of much if any more globulin than was obtained when a cold salt solution was employed.

The trials next to be described have an important bearing on the alterations of proteids which take place in the presence of water.

2. DIRECT EXTRACTION OF THE GROUND OATS WITH TWO-TENTHS PER CENT POTASH SOLUTION.

(Preparation 17).

One hundred grams of freshly-ground oats were treated with 500 cc. of two-tenths per cent potash solution. The mixture, after standing some time, was found to be neutral to litmus-paper. It was then strained through a coarse cloth to remove the husks, and the residue was treated with 100 cc. of two-tenths per cent potash solution and squeezed out nearly dry. The solutions and washings were united and 100 cc. two-tenths per cent potash solution added thereto, making 700 cc. in all. The liquid was then faintly alkaline to litmus. On standing, the insoluble matter settled out; the solution was decanted, filtered, and the residue treated again with two-tenths per cent potash solution. The first potash extract was very dark brown in color, the second much lighter. A third extract contained very little proteid. The first and second extracts were united, filtered, and precipitated with acetic acid added to acid reaction, washed thoroughly with water, alcohol, and ether, and dried over sulphuric acid. The preparation weighed 7.8 grams. A portion treated with two-tenths per cent potash lye was completely soluble, giving a perfectly clear solution. The rest of the preparation was treated with hot alcohol of 0.9 sp. gr. which took up a little proteid. It was washed with hot alcohol of 0.9 sp. gr. until nothing more was removed, then with absolute alcohol and finally with ether, and was dried over sulphuric acid. After drying at 110° C. the substance was analysed with the following results:

Oat proteid directly extracted with two-tenths per cent potash solution (17).

	I.	II.	Ash free. I.	Ash free. II.
Carbon	52.96		53.19	
Hydrogen	6.93		7.01	
Nitrogen	16.23	16.10	16.29	16.26
Sulphur	0.98		0.99	
Oxygen			22.12	
Ash	1.00			
			100.00	

Ash.—0.7063 gram, dried at 110° C. gave 0.0071 gram of ash=1.00 per cent.

Carbon and hydrogen.—0.2651 gram gave 0.5148 gram CO_2=52.96 per cent C, and 0.1654 gram H_2O=6.93 per cent H.

Nitrogen I (Kjeldahl method).—0.7395 gram gave ammonia=14.6 cc. HCl (1 cc.=0.00822 gram N)=16.23 per cent N.

Nitrogen II (Dumas method).—0.4285 gram gave 59.82 cc. nitrogen at 15° C. (barometer 751.5 mm. at 21° C.)=16.10 per cent N.

Sulphur.—0.5196 gram gave 0.0373 gram $BaSO_4$=0.00512 gram S=0.98 per cent S.

3. DIRECT EXTRACTION OF THE GROUND OATS WITH SODIUM CARBONATE SOLUTION.

(Preparation 17 A.)

One hundred grams of ground oats were digested with a 1 per cent sodium carbonate solution, the extract was filtered and the sodium carbonate converted into bicarbonate by treatment with carbon dioxide. The solution was then saturated with ammonium sulphate and the heavy precipitate filtered off. This precipitate was washed with a saturated solution of ammonium sulphate until the washings no longer reacted alkaline. The precipitate was then thoroughly extracted with 10 per cent salt solution until all globulin was separated (see X p. 55) and after

washing out the sodium chloride the residue was extracted with warm 80 per cent alcohol until all the proteid soluble in that liquid was removed.

The residue was then found to be quite insoluble in one per cent sodium carbonate solution and was therefore treated with two-tenths per cent caustic potash solution, filtered, and the dissolved proteid completely precipitated by neutralizing with dilute acetic acid. After washing this substance with water, alcohol, and ether, and drying at 110° C. its composition was as follows:

Oat proteid extracted from ground oats by sodium carbonate solution (**17 A.**)

	I.	II.	Ash-free. I.	Ash-free. II.
Carbon	53.25		53.63	
Hydrogen	7.13		7.18	
Nitrogen	15.99	15.89	16.11	16.01
Sulphur	0.81		0.82	
Oxygen			22.26	
Ash	0.72			
			100.00	

Ash.—0.5661 gram substance dried at 110° C. gave 0.0041 gram ash=0.72 per cent.

Carbon and hydrogen.—0.3269 gram dried substance gave 0.6383 gram CO_2=53.25 per cent C. and 0.2096 gram H_2O=7.13 per cent H.

Nitrogen, I.—0.3637 gram dried substance gave 49.33 cc. N. at 13° C. (barometer 761.5 mm. at 25° C.)=15.99 per cent N.

Nitrogen, II.—0.3916 gram dried substance gave 52.95 cc. N. at 13° C. (barometer 759.2 mm. at 23° C.)=15.89 per cent N.

Sulphur.—0.5000 gram dried substance gave 0.0295 gram $BaSO_4$=0.0041 gram S=0.81 per cent S.

If this analysis is compared with that of preparation **17**, which was obtained from ground oats by direct extraction with two tenths per cent potash solution, it will be seen that the two agree closely.

	17 A.	17.
Carbon	53.63	53.49
Hydrogen	7.18	7.01
Nitrogen	16.11	16.39
Sulphur	0.81	0.99
Oxygen	22.27	22.12
	100.00	100.00
Ash	0.72	1.00

4. EXTRACTION OF THE GROUND OATS WITH WEAK POTASH SOLUTION AFTER ONE HOUR'S TREATMENT WITH WATER.

(Preparation **18.**)

One hundred grams of ground oats were next treated with 800 cc. of water, the mixture was passed through a cloth to remove husks, and the residue washed with 200 cc. of water. The liquid, with suspended starch, etc., was made up to the volume of a liter, and, after the oats had been for an hour in contact with the water, an equal volume of two-tenths per cent potash solution was added and intermixed.

After standing over night the strongly-colored solution was decanted from the residue, filtered, precipitated with acetic acid, the precipitate washed with hot alcohol until nothing more could be removed, and then with absolute alcohol and ether, and dried over sulphuric acid. This preparation weighed 4.25 grams. The residue was treated a second time with two-tenths per cent solution of potash and *very little* more proteid was extracted. After drying at 110° C. this preparation was analysed with the following results:

Oat proteid extracted by two-tenths per cent potash solution after one hour's contact of the ground oats with water (18).

	I.	II.	Ash free. I.	Ash free. II.
Carbon	51.51	.....	52.36	.....
Hydrogen	7.16	.....	7.27	.....
Nitrogen	16.95	17.03	17.23	17.31
Sulphur	0.69	.....	0.70	.....
Oxygen	.....	.....	22.44	.....
Ash	1.63	.....	.....	.....
			100.00	.....

Ash.—0.2760 gram, dried at 110° C., gave 0.0045 gram ash=1.63 per cent.

Carbon and hydrogen.—0.2953 gram gave 0.5576 gram CO_2=51.51 per cent C, and 0.1904 gram H_2O=7.16 per cent H.

Nitrogen, I (Kjeldahl method).—0.5867 gram gave ammonia = 12.1 cc. HCl (1 cc. = 0.00822 gram N) = 16.95 per cent N.

Nitrogen, II (Dumas method).—0.5120 gram gave 75.49 cc. N at 15° C. (barometer 753.6 mm. at 23° C.) = 17.03 per cent N.

Sulphur.—0.7210 gram gave 0.0365 gram $BaSO_4$ = 0.005013 S = 0.69 per cent S.

In this analysis the fusible ash made the combustion of the last traces of carbon difficult; hence, probably ash and nitrogen are stated a little too high and the carbon is slightly inaccurate.

5. EXTRACTION WITH POTASH SOLUTION AFTER A DAY'S CONTACT OF THE GROUND OATS WITH WATER.

(Preparation 19.)

One hundred grams of oats were treated in the manner just described, except that instead of the 1,000 cc. of potash solution first added, 1,000 cc. of distilled water were used. After standing a day, the aqueous solution, which had become clear, was decanted, and 1,000 cc. of two-tenths per cent potash solution were added to the residue and let stand upon it over night. The solution was then decanted from the residue, filtered, precipitated with acetic acid, the precipitate was washed with hot alcohol of 0.9 sp. gr. and with absolute alcohol and ether, and dried over sulphuric acid. The preparation weighed 2.55 grams. The following figures were obtained in its analysis:

Oat proteid, extracted by two-tenths per cent potash solution after one day's contact with water, 19

		Ash-free.
Carbon	52.29	52.61
Hydrogen	6.88	6.92
Nitrogen	16.89	16.99
Sulphur	0.89	0.89
Oxygen	22.46	22.59
Ash	0.59	.....
	100.00	100.00

Ash.—0.5578 gram, dried at 110° C., gave 0.0033 gram ash = 0.59 per cent.

Carbon and hydrogen.—0.3300 gram gave 0.6327 gram CO_2 = 52.29 per cent C, and 0.2042 gram H_2O = 6.88 per cent H.

Nitrogen (Kjeldahl method).—0.5426 gram gave ammonia = 11.15 cc. HCl (1 cc. = 0.00822 gram N) = 16.89 per cent N.

Sulphur.—0.8310 gram gave 0.0513 gram $BaSO_4$ = 0.00746 gram S = 0.89 per cent S.

The three preparations last described were made by extraction with the same dilute potash solution, and under essentially the same conditions in all respects, with the single difference that, while in case of 17 the oats were directly treated with this solvent, 18 was extracted by potash solution after the ground oats had been kept in contact with water for one hour, and 19 after digestion with water for twenty-four hours.

The amount of proteid extracted in the first instance was 7.80 grams (17).

The amount of proteid extracted in the second instance was 4.25 grams (18).

The amount of proteid extracted in the third instance was 2.55 grams (19).

The composition of the three preparations is placed in comparison with that of the oat globulin 13 in the subjoined statement.

	Oat proteid, extracted by—			
	Potash solution.			
	Salt solution, direct.	Direct.	After contact with water for	
			1 hour.	24 hours.
	13.	17.	18.	19.
Carbon	52.32	53.49	52.36	52.61
Hydrogen	7.19	7.01	7.27	6.92
Nitrogen	16.95	16.39	17.23	16.99
Sulphur	0.88	0.99	0.70	0.89
Oxygen	22.66	22.12	22.44	22.59
	100.00	100.00	100.00	100.00

The experiments just detailed tend to show that the action of water upon the crushed oat kernel induces rapid changes of composition in these proteids simultaneously with their conversion into insoluble modifications.

They also indicate that the *globulin* itself is a result of changes brought about in the presence of water and is not a body existing as such, ready-formed, in the oats.

6. NORTON'S AVENINE AND KREUSLER'S OAT LEGUMIN.

The substance extracted directly by potash solution without previous exposure of the oats to water, 17, is probably the same as that which Johnston and Norton originally termed *avenine*, and which the latter obtained by digesting ground oats in water to which a little ammonia was added to prevent souring, as the weather was very warm.* The preparation which Norton analyzed as avenine was, however, extracted by water alone, and was accordingly a mixture.† Both Norton and Kreusler applied weak alkali solution to the extraction of proteid bodies from oats *after* the ground grain had been subjected to the action of water.

Norton made and analyzed two preparations, accomplishing the extraction by means of dilute ammonia, and threw down the proteid by adding acetic acid to the ammoniacal solution. One preparation, "A," was redissolved in strong ammonia at nearly the boiling point, and again precipitated by acetic acid, then washed (presumably with water) and boiled in alcohol and ether until no more fatty matter was taken up. Another preparation, "B," was boiled in alcohol and ether *before* redissolving in very dilute ammonia at 70° to 80° C.

Norton made a single analysis of A and two fairly accordant analyses of B, the average of which is the basis for the corrected analysis given below. He found in both substances 1 per cent of phosphorus, which he includes in the analyses reckoned ash free. This phosphorus in A nearly equals, and in B exceeds, the ash. If this phosphorus be deducted and the analyses recalculated to a percentage statement, we have the corrected analyses given below. As Norton published no analytical details and used a method of doubtful accuracy (Berthier's) for estimating phosphorus, this correction is perhaps not altogether satisfactory. Norton's nitrogen determinations were all by Dumas's method. He gives to this substance no special name, but designates it as a "protein body" simply.

* Am. J. Sci. [2] 5, 23.

† Loc. cit., p. 28.

Kreusler's preparation of "*oat legumin* **A**" was obtained by suspending 1½ pounds crushed oats in 5 liters of water, adding, to neutralize the acidity, over 3 grams of potassium hydroxide. The mixture stood twelve hours in a cool place, was then thrown on a sieve, the residue washed with water, and the liquid left to rest over night. The turbid liquid was poured off and acidified with acetic acid. The precipitate was washed first with alcohol of 40 per cent, then with that of 80 per cent, then with ether, and lastly was treated with absolute alcohol and dried over sulphuric acid and at 100° C. To purify this substance from starch, it was dissolved in dilute potash (1 gram to the liter of water), and from the solution, after deposition of all suspended matter, it was thrown down again by acetic acid, washed and dried.

Another preparation, **B**, was obtained from oats that had been extracted by cold alcohol—and a third, **C**, from oats exhausted with hot alcohol—previous to treatment with weak potash solution. The analyses of **A** and **C**, corrected by deduction of ash and phosphoric acid, are here tabulated. In his preparation B, Kreusler found 16.74 per cent of nitrogen, but carried the analysis no further.

	Proteïd obtained from ground oats after treatment with water by extracting with weak solution of			
	Ammonia (Norton).		Potash (Kreusler).	
	A	**B**	**A**	**C**
Carbon	53.72	52.35	52.09	51.58
Hydrogen	7.00	6.93	8.03	8.01
Nitrogen	16.94	16.55	16.83	17.61
Sulphur	0.60	1.12	0.96	.....
Oxygen	21.74	23.05	22.09	.....
	100.00	100.00	100.00	.....

Norton remarks of his preparation **A** that dissolving it in hot strong ammonia would seem to have darkened the color and somewhat affected the composition. It will be observed that Norton's **B** does not differ greatly from my analyses **13** and **19**.

Kreusler, doubting the purity of his preparations, boiled them in alcohol of 60 per cent, and finding that something was thereby dissolved, especially from **A**, continued this treatment as long as anything was removed. The dissolved substance contained 16.38 per cent of nitrogen. The thus "purified" preparations had the following composition, ash-free:

	A.	**C.**	Average.
Carbon	51.40	51.85	51.63
Hydrogen	7.49	7.49	7.49
Nitrogen	17.29	17.03	17.16
Sulphur	0.85	0.73	0.79
Oxygen	22.97	22.90	22.93
	100.00	100.00	100.00

The average of the last two analyses Kreusler gives as expressing the composition of oat legumin.* He observes, in concluding his paper, that the substance purified by long boiling with alcohol had almost entirely lost solubility both in potash and acetic acid. It was in fact converted into coagulated proteid; but that the change of composition was not entirely due to the removal of impurities and in part at least was owing to alteration of the substance itself must be regarded as almost certain. It is to be concluded that the "globulin" extracted by 10 per cent salt solution and the "legumin" removed by dilute potash solution after action of water upon the crushed grain are very similar, perhaps identical in composition, and that neither of them

*In a paper already referred to (Pflüger's Archiv, 18, 236), Ritthausen decided that the soda-lime method used by Kreusler was untrustworthy, and stated as the result of his own analysis by Dumas's method the nitrogen content of *oat legumin* to be 17.45 per cent. It is now well understood that Dumas's method, carried out as Ritthausen describes in the paper referred to, usually gives too high results, due to retention of air in the oxide of copper, etc., and formation of carbon monoxide during the combustion. (See Report Conn. Station, 1878, p. 111, and 1879, p. 124.

preëxists in the grain; but the investigation on these points is not altogether conclusive and needs to be continued.

Assuming that Kreusler's analyses are correct, there can be little doubt that his oat legumin as finally analyzed was different from the proteid at first existing in the potash extract and was essentially altered in composition as well as in solubility during the processes of preparation and "purification."

VII.—Proteid extracted by Hot Sodium Chloride Solution.

(Preparation 20.)

Freshly ground oats were treated with distilled water heated to 65° C. and then sufficient sodium chloride was added to make a 10 per cent solution. When the addition of salt was begun the liquid had a temperature of 60° C.; when finished the temperature was 45°. The mixture was digested for about an hour at 45° and a portion of the extract was filtered. The filtrate became turbid immediately on cooling. When gently warmed the turbidity completely disappeared. The perfectly clear solution on further heating coagulated as follows: At 57° C. a very slight turbidity was seen that increased but little up to 78°, whence it rapidly augmented with formation of flocks at 85°.

The remainder of the extract, together with the crushed oats, was heated up to 75° and filtered as rapidly as possible. A perfectly clear filtrate was obtained which became turbid on cooling. The vessel containing the hot extract was placed in a large water bath at 75° and cooled very slowly. A dense deposit formed which closely adhered to the bottom of the dish and under the microscope was seen to consist entirely of minute *spheroids* about 0.01 mm. in diameter.

The residual oats, extracted twice again, yielded little more to the hot salt solution. The proportion of proteid thus obtained was apparently little, if any, greater than that dissolved by sodium chloride solution at 15° to 20°.

The deposit of spheroids was almost wholly freed from the mother liquor by simple decantation and was treated with cold 10 per cent sodium chloride solution, in which it dissolved very slowly. On warming to about 40° the substance melted to a soft, plastic mass, which became softer as the temperature rose and could be drawn out into glistening threads. At 65° the substance became so fluid that the mass broke up and rapidly dissolved to a clear solution.

When a portion of this solution was heated to 78° a slight turbidity developed that increased very little up to 98°, at which point a few flocks separated. These were filtered out, and the filtrate gave on boiling a considerable coagulum. The filtrate from this coagulum yielded another precipitate on boiling again, and the same result followed these operations to the fourth time. The final filtrate gave with hydrochloric acid a copious precipitate.

This substance was now prepared in greater quantity in the following manner: Five pounds of ground oats were treated with twelve liters of 10 per cent sodium chloride solution, strained through a hair sieve to remove the husks and then heated to 60° in a water bath of 70° and maintained at that temperature for an hour. The extract was then filtered as rapidly as possible. The extract, after decanting from a deposit which separated out on cooling, was saturated with pure ammonium sulphate, and the precipitate thus formed was filtered off and added to the deposit formed on cooling. The substance thus obtained was then treated with three liters of 10 per cent sodium chloride solution heated to 65° in a water bath of 70° and filtered as rapidly as possible on a funnel surrounded by hot water. The clear filtrate, which became turbid at once on cooling, was received in a vessel set in a large water bath heated to 70°, and the whole was allowed to cool very slowly. When cold the liquid was decanted from the dense deposit that adhered to the bottom and sides of the beaker.

As the substance dissolved to an opalescent solution in distilled water, it was washed with 50 per cent alcohol as long as with silver nitrate any chlorine was discoverable in the washings; then the washing was continued with absolute alcohol and with ether, and the substance dried over sulphuric acid; 8.5 grams of substance were thus obtained. The salt solution from which the spheroids had deposited was next dialyzed, and the proteid which separated out on the removal of the salts was filtered off, washed in succession with dilute alcohol, absolute alcohol, and ether, and dried over sulphuric acid. This preparation weighed 5.64 grams.

The residue of the oats was extracted a second time in the same manner and the solution was at once saturated with ammonium sulphate. The precipitate thus produced was washed directly with 50 per cent alcohol; but, since the substance dissolved on washing with dilute alcohol as long as much ammonium sulphate remained, the final yield was only 2.6 grams.

The product obtained from the solution of the first ammonium sulphate precipitate in hot brine has the following properties: Under the microscope before washing, it appears to be perfectly homogeneous and to consist entirely of spheroids about 0.01 mm. in diameter. After washing and drying it forms a dense, snow-white powder. In cold distilled water it dissolves to an opalescent solution which gives a heavy precipitate on the addition of a little sodium chloride; a little more sodium chloride precipitates the aqueous solution almost completely, and on addition of still more salt this precipitate is again dissolved.

Hot distilled water dissolves this proteid completely to a perfectly clear solution from which a considerable part of the substance deposits on cooling.

Dilute acetic acid alone gives no precipitate in the aqueous solution; addition of a little salt together with the acid precipitates it. The precipitate thus produced is soluble in alcohol of 0.9 sp. gr.

When treated with hot dilute alcohol the substance melts and remains suspended in the solution in transparent droplets; addition of a little salt produces no change, but addition of a little acetic acid gives a clear solution. This solution in alcohol, on cooling, forms a very bulky, transparent jelly. On evaporation, the substance separates as a skin on the surface, which is readily soluble again in dilute alcohol of 0.9 sp. gr.

On analysis the composition of the dried spheroids was found to be as follows:

Oat proteid extracted by sodium-chloride solution at 65° C. (20).

	I.	II.	Ash-free.	
			I.	II.
Carbon	52.13	52.16	52.20	52.24
Hydrogen	6.93	7.02	6.94	7.03
Nitrogen	17.72	17.87	17.75	17.90
Sulphur	0.81	0.73	0.81	0.73
Oxygen			22.30	22.10
Ash	0.19			
			100.00	100.00

Ash.—0.4694 gram substance, dried at 110° C., gave 0.0009 gram of ash = 0.19 per cent.

Carbon and hydrogen, I.—0.3639 gram dried substance gave 0.6955 gram $CO_2 = 52.13$ per cent C. and 0.2270 gram $H_2O = 6.93$ per cent H.

Carbon and hydrogen, II.—0.4728 gram dried substance gave 0.9036 gram $CO_2 = 52.16$ per cent C. and 0.2985 gram $H_2O = 7.02$ per cent H.

Nitrogen, I (Kjeldahl method).—0.7768 gram substance gave ammonia = 16.75 cc. HCl Sol. (1 cc. = 0.00822 gram N) = 17.72 per cent N.

Nitrogen, II (Dumas method).—0.4080 gram dried substance gave 62.36 cc. N at 15° C. (barometer 762 mm. at 21° C.) = 17.87 per cent N.

Sulphur, I.—0.7841 gram dried substance gave 0.0463 gram $BaSO_4 = 0.0064$ gram S = 0.81 per cent S.

Sulphur, II.—0.8670 gram dried substance gave 0.0460 gram $BaSO_4 = 0.0063$ gram S = 0.73 per cent S.

The fact that this substance separated from warm sodium chloride solutions so readily in the form of spheroids indicated that, under proper conditions, it might be obtained in recognizable crystals. After a very large number of attempts, which resulted only in the production of spheroids, a portion of that substance, which had deposited on dialyzing the mother liquor from 20, was converted into a mixture of spheroids and crystals. The latter were about 0.1 mm. in their greatest diameters and to all appearance had distinct rhombic faces, but they were not perfectly developed.

These crystals were obtained by saturating with the globulin a 10 per cent sodium chloride solution heated to about 60° C., and allowing it to cool slowly in a large bath of warm water.

After many trials with preparation **20** a portion of it was completely converted into perfectly-formed octahedral crystals, which Prof. S. L. Penfield, of Yale University, kindly examined and pronounced to be isometric. These crystals were obtained by dissolving some of the substance in cold distilled water and cautiously adding sodium chloride until a copious precipitate resulted. On immersing the test tube in warm water the precipitate dissolved to a perfectly clear solution. This solution was then allowed to cool slowly in a bath containing about four liters of water heated to 60° C. After a day the deposit was examined under the microscope and found to consist entirely of crystals.

By saturating *distilled water* heated to 60° C. with preparation **20** and allowing the solution, surrounded by a large volume of warm water, to cool slowly, an abundant deposit of octahedral crystals was obtained, which were, however, not quite so perfectly developed as those just described.

VIII.—Proteid derived from the "Albuminate."

(Preparations 21, 22, and 23.)

On treating 10 pounds of freshly ground oats with brine, precipitating the filtered solution by saturating with ammonium sulphate, and extracting the precipitate thus obtained with brine, it was found that a very large part of the globulin originally dissolved had been converted into the so-called "albuminate." After washing this latter thoroughly with brine, to free it completely from the unchanged globulin, it was dissolved in a 1 per cent sodium carbonate solution. About two-thirds of this solution was then treated with carbon dioxide for three hours, whereby a heavy white precipitate settled out. This precipitate was collected on a filter and allowed to drain over night. The next morning it was found to have become transparent and gummy about the edges.

This precipitate was now completely soluble in salt solution and had all the properties of the globulin (**20**) previously obtained from the hot sodium chloride extract. The entire precipitate was then dissolved in one liter of brine and dialyzed for four days, during which time all but a trace of the substance separated out. The thus precipitated proteid was seen under the microscope to consist of spheroids of about one-tenth of a millimeter diameter or less, similar to those obtained by cooling a warm solution of the globulin. After filtering off, washing with alcohol, ether, and absolute alcohol, 21 grams of air-dried material were obtained. This substance was completely soluble in brine and was precipitated therefrom by diluting with water, or by saturating with sodium chloride, or by adding minute quantities of hydrochloric, nitric, or acetic acid. In the entire absence of salts, extremely small amounts of the just-named acids dissolved the proteid instantly and completely, but the addition of a little sodium chloride precipitated it from this solution, the extent of the precipitation depending on the relative quantities of the acid and salt present. The precipitation was complete when certain proportions of salt and acid were used. Addition of strong soda lye to the solution of the proteid in dilute acid gave a heavy precipitate, which dissolved but slowly in excess of soda, although the final mixture contained over 25 per cent of sodium hydrate. Addition of copper sulphate to this alkaline solution gave a violet color. With Millon's reagent and with nitric acid, the usual proteid reactions were obtained. Alcohol containing a minute amount of free acid dissolved the substance completely. Its composition was found to be as follows:

Oat proteid derived from sodium carbonate solution of the "albuminate" (**21**).

			Ash-free.	
	I.	II.	I.	II.
Carbon	52.28	.....	52.30	.....
Hydrogen	6.98	.....	6.98	.....
Nitrogen	17.86	17.73	17.86	17.73
Sulphur	0.69	.....	0.69	.....
Oxygen	.....	.....	22.17	.....
Ash	0.03	.....	.....	.....
			100.00	

Ash.—0.6759 gram substance dried at 110° C. gave 0.0002 gram of ash = 0.03 per cent.

Carbon and hydrogen.—0.1610 gram dried substance gave 0.8837 gram CO_2 = 52.28 per cent C., and 0.3220 gram H_2O = 6.98 per cent H.

Nitrogen, I (Dumas method).—0.3474 gram dried substance gave 52.15 cc. N. at 13° C. (barometer 768.2 mm at 23° C.) = 17.86 per cent N.

Nitrogen, II (Kjeldahl method).—1.0108 gram dried substance gave ammonia = 21.8 cc. HCl Sol. (1 cc. = 0.00822 gram N.) = 17.73 per cent N.

Sulphur.—0.7695 gram dried substance gave 0.0380 gram $BaSO_4$ = 0.0052 gram S = 0.69 per cent S.

In all respects save one this substance behaved exactly like the globulin obtained by extracting ground oats with hot sodium-chloride solution. The latter proteid dissolved to a turbid solution in cold, and to a perfectly clear solution in hot, distilled water. So far as the usual methods of analysis show, the two bodies are identical in composition, as is seen from the following figures:

	Globulin extracted from oats by hot sodium-chloride solution. Average of two analyses. Preparation 20.	Globulin derived from sodium carbonate solution of "albuminate." Preparation 21.
Carbon	52.22	52.30
Hydrogen	6.98	6.98
Nitrogen	17.82	17.86
Sulphur	0.77	0.69
Oxygen	22.21	22.17
	100.00	100.00
Ash	0.19	0.03

Another preparation of this substance was made by dissolving a second portion of the "albuminate" in 2 per cent sodium-carbonate solution, precipitating with carbon dioxide, washing thoroughly with water, dissolving in brine, and diluting the solution with a large amount of water. The final snow-white precipitate was filtered off, and after washing with alcohol and ether weighed 11 grams. Its properties are the same as those of 21, except that it is slightly soluble in hot distilled water. Its composition as determined by analysis here follows:

Oat proteid derived from sodium carbonate—Solution of the "albuminate" (22).

		Ash-free.
Carbon	51.98	52.05
Hydrogen	6.92	6.93
Nitrogen	17.83	17.85
Sulphur	)	
Oxygen	)	23.17
		100.00
Ash	.13	

Ash.—0.5437 gram substance, dried at 110° C., gave 0.0007 gram ash=0.13 per cent.

Carbon and hydrogen.—0.5789 gram dried substance gave 1.1030 gram CO_2=51.98 per cent C., and 0.3609 gram H_2O =6.92 per cent H.

Nitrogen.—0.4230 gram dried substance gave 63 cc. N at 13° C. (barometer 773 mm. at23° C.)=17.83 per cent N.

The filtrate from the precipitate produced by carbon dioxide in the preparation of the preceding substance (22) was diluted with an equal volume of water, further treated with carbon dioxide for about three hours, and allowed to stand over night. The resulting precipitate was filtered off and washed with water, alcohol, and ether. Five grams of substance having the same

properties as preparations **21** and **22** were thus obtained. Analysis of this product gave the following results:

Oat proteid derived from sodium carbonate solution of the "albuminate" (**23**).

		Ash-free.
Carbon	52.16	52.35
Hydrogen	7.00	7.02
Nitrogen	17.68	17.73
Sulphur	0.73	0.73
Oxygen		22.17
		100.00
Ash	0.36	

Ash.—0.5500 gram substance, dried at 110° C., gave 0.0029 gram of ash=0.36 per cent.

Carbon and hydrogen.—0.4388 gram dried substance gave 0.8393 gram CO_2=52.16 per cent C., and 0.2766 gram H_2O=7.00 per cent H.

Nitrogen.—0.3659 gram dried substance gave 54.36 cc. N at 13° C. (barometer 767.6 mm. at 22° C.)=17.68 per cent N.

Sulphur.—0.9135 gram dried substance gave 0.0484 gram $BaSO_4$=0.0066 gram S=0.73 per cent S.

IX.—Crystallization of the Globulin obtained from the so-called "Albuminate."

Three hundred cubic centimeters of 1 per cent sodium chloride solution were heated to 70° C., with 5 grams, *i. e.*, an excess of preparation **21**, and filtered on a steam-jacketed funnel. On cooling, the filtrate rapidly deposited a large crop of apparently rhombohedral crystals. The residue undissolved by the hot 1 per cent brine was washed with the same weak brine heated to 70°. On

cooling, the washings deposited octahedral crystals. This process was repeated several times with other portions of preparation 21. In most cases the filtrate deposited apparently rhombohedral and the washings octahedral crystals. The residues, which had been filtered out, were as far as possible dissolved and crystallized, from 1 per cent brine yielding either octahedral crystals or mixtures of octahedra and rhombohedra. The different crops of crystals were collected on separate filters, according as they were wholly rhombohedra or octahedra, or mixtures of the two. Three preparations, 24, 25, and 26, were obtained in this way, which were, as usual, washed with water, alcohol, and ether, and dried at 110° for analysis. Thus prepared they retained their crystalline form entirely unchanged, and had in all respects the same properties as the mother substance 21. The accompanying plate, from a photograph, for which I am indebted to Prof. M. C. White, illustrates these crystals and a single spheroid, magnified about 800 diameters. Prof. S. L. Penfield examined these crystals and states that they appear to be rhombohedra and octahedra, although the former have no action on polarized light. He suggests that the apparent rhombohedra may be octahedra with but six faces developed, such crystals occurring in nature, but as their diameters are but a few hundredths of a millimeter, this point can not be definitely determined by measurement. Analyses of the three preparations gave the following percentages:

Crystallized Oat-Proteid, derived from 21.

(Preparation 24.)

		Ash-free.
Carbon	52.14	52.17
Hydrogen	6.96	6.96
Nitrogen	17.92	17.93
Sulphur	0.53	0.53
Oxygen	.....	22.41
Ash	0.06	.....
		100.00

Ash.—0.4600 gram substance dried at 110° C. gave 0.0003 gram of ash=0.06 per cent.

Carbon and hydrogen.—0.4463 gram dried substance gave 0.8835 gram CO_2=52.14 per cent C. and 0.2795 gram H_2O=6.96 per cent H.

Nitrogen.—0.4042 gram dried substance gave 63.0cc. N. at 17° C. (barometer 756.3mm. at 21° C.)= 17.92 per cent N.

Sulphur.—0.6345 gram dried substance gave 0.0242 gram $BaSO_4$=0.0033 gram S=0.53 per cent.

Crystallized Oat-Proteid, derived from 21.

(Preparation 25.)

		Ash-free.
Carbon	52.00	52.11
Hydrogen	7.09	7.10
Nitrogen	17.91	17.94
Sulphur	.....	22.85
Oxygen	.....	
Ash	0.20	.....
		100.00

Ash.—0.2035 gram substance dried at 110° C. gave 0.0004 gram ash=0.20 per cent.

Carbon and hydrogen.—0.2562 gram dried substance gave 0.4885 gram CO_2=52.00 per cent C. and 0.1635 gram H_2O=7.09 per cent H.

Nitrogen.—0.3935 gram dried substance gave 61.3cc N. at 17° C. (barometer 756. 5mm. at 21° C.)=17.91 per cent N.

Crystallized Oat-Proteid, derived from **21.**

(Preparation **26.**)

		Ash-free.
Carbon	52.23	52.25
Hydrogen	7.08	7.08
Nitrogen	17.81	17.82
Sulphur	0.52	0.52
Oxygen	.....	22.33
Ash	0.05	.....
		100.00

Ash.—0.3974 gram substance dried at 110° C. gave 0.0002 gram ash=0.05 per cent.

Carbon and hydrogen.—0.2866 gram dried substance gave 0.5489 gram CO_2=52.23 per cent C. and 0.1828 gram H_2O=7.08 per cent H.

Nitrogen.—0.3123 gram dried substance gave 48.31cc. N at 17° C. (barometer 757^{mm}. at 21° C)= 17.82 per cent N.

Sulphur.—0.3598 gram dried substance gave 0.0135 gram $BaSO_4$=0.0018 gram S=0.52 per cent.

Crystalized oat globulin, derived from **21.**

	Rhombohedra.	Rhombohedra and octahedra.	Octahedra.
	24.	**25.**	**26.**
Carbon	52.17	52.11	52.25
Hydrogen	6.96	7.10	7.08
Nitrogen	17.93	17.94	17.82
Sulphur	0.53	22.85	0.52
Oxygen	22.41		22.33
	100.00	100.00	100.00
Ash	0.06	0.20	0.05

No chlorine could be detected in these crystals. It is thus shown that the crystallized globulin, except for its slightly lower content of sulphur, has the same composition as the mother substance, and agrees in all respects with the globulin obtained directly from ground oats by extraction with hot salt solution, except that it is not soluble in water and contains a little less sulphur.

It is further to be noted that the methods of preparation were suited to fractionally separate the substance into its component parts, had it been a mixture of two or more globulins. It seems improbable that the sodium chloride, which Grübler found in his crystallized globulin from squash seed, was anything more than an accidental impurity. The ash of Grübler's preparations contained traces of the various salts present in the solutions from which they separated, and there appears to be no good ground for Grübler's assumption that the crystallized proteids are definite compounds of globulin with sodium chloride or with other inorganic bodies, since the content of total mineral matters is variable, and, as in my preparations 24 and 26, sometimes amounts to but .05 per cent of the proteid.

X.—Globulin Obtained by Direct Extraction of Ground Oats with Sodium Carbonate Solution.*

One hundred grams of ground oats were digested with a 1 per cent sodium carbonate solution, the extract was filtered clear, and the sodium carbonate converted into bicarbonate by treatment with carbon dioxide. The solution was then saturated with ammonium sulphate and the

* This extraction is the same as that described on page 71, where the proteid insoluble in sodium chloride solution is specially considered.

heavy precipitate filtered off. This precipitate was washed with a saturated solution of ammonium sulphate until the washings no longer reacted alkaline. The precipitate was then extracted thoroughly with salt solution and this extract dialyzed. After removal of the salts by dialysis, the proteid, which had separated, was filtered off and washed with alcohol and ether. It weighed, air-dry, 1½ grams, being, therefore, about 1½ per cent of the oat kernel. Dried at 110° C., for analysis, it was found to have the following composition:

Oat proteid extracted from ground oats by sodium carbonate solution and soluble in sodium chloride solution.

(Preparation 27.)

	I.	II.	Ash-free. I.	Ash-free. II.
Carbon	51.68	.....	51.82	.....
Hydrogen	6.91	.....	6.93	.....
Nitrogen	17.92	17.91	17.95	17.94
Sulphur / Oxygen \	.....	.....	23.30	.....
Ash	0.26	.....	.....	.....
			100.00	

Ash.—0.2652 gram substance, dried at 110° C., gave 0.0007 gram ash=0.26 per cent.

Carbon and hydrogen.—0.2296 gram dried substance gave 0.4350 gram CO_2=51.68 per cent C and 0.1429 gram H_2O=6.91 per cent H.

Nitrogen, I.—0.3441 gram dried substance gave 52.15 cc. N at 13° C. (barometer 764.0 mm. at 25° C.=17.92 per cent N.

Nitrogen, II.—0.3294 gram dried substance gave 50.14 cc. N at 14° C. (barometer 762.0 mm. at 23° C.)=17.91 per cent N.

XI.—Summary of Analyses of Oat Globulin.

The agreement in the analyses of the eight different preparations of oat globulin extracted by hot salt solution (20) or obtained from "albuminates" (21–27) is seen from the following table:

	20.	21.	22.	23.	24.	25.	26.	27.
Carbon	52.22	52.30	52.05	52.35	52.17	52.11	52.25	51.82
Hydrogen	6.98	6.98	6.93	7.02	6.96	7.10	7.08	6.93
Nitrogen	17.82	17.86	17.85	17.73	17.93	17.91	17.82	17.95
Sulphur	0.77	0.69	23.17	0.73	0.53	22.85	0.52	23.30
Oxygen	22.22	22.17		22.17	22.41		22.33	
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The writer has nowhere found any description of a vegetable proteid like this. Although its proportion of carbon is the same as that of the globulin extracted from oats by cold-salt solution, it nitrogen-content is 1 per cent greater. It contains nearly 1 per cent less of nitrogen, about ½ per cent more of carbon, and but ½ as much sulphur as Chittenden and Hartwell* found in the globulin or "vegetable vitellin" of squash seeds.

Barbieri's analysis of squash-seed globulin agrees fairly well with these analyses of the crystallized oat globulin, but carbon and sulphur are somewhat lower, nitrogen higher, and as regards sulphur and nitrogen his analysis differs materially from the later ones of Chittenden and Hartwell.

Grübler's earlier analyses of squash seed globulin, which gave 53.21 per cent of carbon and 19.22 per cent of nitrogen, were evidently incorrect, and in a recent publication† this chemist

*Journal of Physiology, XI. pp. 437–440.

† Journal für Praktische Chemie XLIV, p. 369.

states the composition of crystallized proteid from squash seed as given below, where the various analyses of vegetable globulin, except this earlier one of Grübler, are tabulated.

I have lately obtained from flaxseed a crystallized globulin whose composition agrees quite nearly with that of squash seed vitellin.

Composition of vegetable globulin.

	Ritthausen.		Barbieri.	Ritthaus.	Chittenden and Hartwell.			Grübler.	Osborne.	
	Hemp (cryst.).	Castor bean (cryst.).	Squash seed (amorph.).	Squash seed (cryst.).	Squash seed (cryst.).	Squash seed (spheroid.).	Squash seed (amorph.).	Squash seed (cryst.).	Flaxseed (cryst.).	Oats (spheroid and cryst.) average.
C	50.98	50.88	51.88	51.61	51.60	52.03	51.81	51.48	51.22	52.19
H	6.92	6.98	7.51	7.00	6.97	6.93	6.94	6.76	6.95	7.00
N	18.73	18.58	18.08	.....	18.80	19.08	18.71	18.14	18.44	17.86
S	0.82	0.77	0.60	.....	1.01	1.04	1.01	0.96	0.82	0.65
O	22.55	22.79	21.93	.....	21.62	20.92	21.53	22.66	22.57	22.30
	100.00	100.00	100.00	.....	100.00	100.00	100.00	100.00	100.00	100.00
Ash	.....	.....	1.11	.....	0.30	0.36	.....	0.18	.....	.....

XII.—Methods of Analysis.

Drying.—Preparations preceding **12** were dried in hydrogen at 110° C. to a constant weight. Those following were dried in air at 110° C.

Carbon and hydrogen.—Carbon and hydrogen were determined by combustion in a platinum boat in open tube filled with copper oxide and containing in addition a layer of lead chromate and a roll of metallic copper. In the analyses preceding that of preparation **12** the portions taken for each carbon determination were dried separately to a constant weight at 110° C. in a stream of hydrogen, and weighed in a closed tube. For those following, the entire sample was dried to a constant weight in air. By the latter method of drying, slightly higher percentages of hydrogen were obtained when the substance analyzed was in the form of a light hygroscopic powder; the dense preparations obtained from alkaline solutions, not being so hygroscopic, gave slightly lower percentages of hydrogen. The difference is attributable to moisture unavoidably absorbed by the dry, light powder during weighing and transferring to the combustion-tube, the analyses being made in very damp summer weather.

The accuracy of the determinations was repeatedly controlled by analyses made on pure sugar.

Nitrogen.—Nitrogen determinations were made by both the Kjeldahl and Dumas methods, in the manner customarily followed in the laboratory of this station.* Preceding **12** the determinations were made upon the substance dried over sulphuric acid, a correction being applied for the moisture contained in the sample as found by drying it at 110° C. Subsequent determinations were made on the fully-dried sample.

Sulphur.—Sulphur was determined by fusion with sodium hydroxide and potassium nitrate, dissolving the fused mass in water, neutralizing the alkali with a considerable excess of hydrochloric acid, evaporating to dryness to decompose nitrates and to remove excess of acid, dissolving the dry residue in 600 or 700 centimeters of water, allowing the solution to stand for twenty-four hours, filtering, heating to boiling, and precipitating with 3 cc. of a 10 per cent solution of barium chloride.

In the analyses of **8**, evaporation to dryness was omitted, the barium sulphate being fused with sodium carbonate and reprecipitated. In all cases the ash of the preparations was carefully examined for sulphates, but none was found in any instance.

Blank experiments with the reagents proved them to be entirely free from sulphur.

Ash.—Ash was determined by combustion in a platinum crucible, no difficulty being experienced in burning any of the preparations except **18**.

*Annual report of the Connecticut Agricultural Experiment Station for 1879, p. 124, and American Chemical Journal, vol. 2, p. 27.

XIII.—Summary of Results.*

1. The proteid body removed from fresh-ground oats by direct extraction with weak alcohol—first observed by Norton and by him designated *glutin*—when dehydrated by absolute alcohol and dried over sulphuric acid, is a light yellowish powder, insoluble in pure water as well as in absolute alcohol, soluble in mixtures of alcohol and water, soluble also in dilute acids and alkalies, and from these solutions thrown down by neutralization. Separated from its solution in alcohol of 60 per cent by evaporating off the alcohol, it forms a yellowish, slimy mass. Its composition (as found for preparation 8†) is given in the table, under I. This substance is remarkable for its considerable content of sulphur, which is exceeded by that of keratin alone among the proteids, and is otherwise equaled only by that recorded in some analyses of serum albumin. (See pp. 57–59.)

2. When the substance described above is heated with dilute alcohol for some time it coagulates and becomes insoluble in that liquid, but without apparent change of composition. II is the average of three accordant analyses of this coagulated form of the alcohol soluble proteid, made on preparations **4 A**, **4 B**, and **7** (pp. 55–57).

Kreusler obtained this material from the oat, but what Ritthausen and he named *oat-gliadin* was a product of its further alteration by the chemical treatment to which it was subjected with a view of purification. (See pp. 58–59.)

3. When oats are first treated with water or 10 per cent solution of common salt, before extraction with dilute alcohol, the alcohol soluble proteid undergoes alteration, and a body of different composition and properties results. In the table, III, gives the mean of closely agreeing analyses of this substance made on preparations **9**, **10**, **11**, and **12**; it is much more soluble in dilute alcohol than I, and is not coagulated or transformed into an insoluble modification. When wet with absolute alcohol, the moisture attracted from the air shortly renders it gummy and tenaciously adhesive, unlike I (pp. 59–63).

Its composition as regards carbon, hydrogen, and nitrogen, is very near to that found by Dumas and Cahours, and also by v. Bibra, for *gliadin* or *plant gelatin* (extracted by hot alcohol from wheat gluten and remaining dissolved in the alcohol when cold).

4. The chief proteid extracted by cold 10 per cent salt solution behaves towards reagents like the *myosin globulin* from animal muscle, as first stated by Weyl. Contrary to Weyl's observations, however, the coagulation temperature (80°–100°) is much higher than that of animal myosin (55°–60°). This proteid appears to be the result of a transformation similar to that by which myosin is formed from myosinogen. Its composition—the average of several analyses on preparations **13** and **14**—is given under IV (table), and is very near to that of muscle myosin. The greatest proportion of this proteid extracted by salt solution from the oat was 1.3 per cent. (See pp. 65–68.)

5. The proteid extracted, after complete exhaustion of the oats with alcohol of 0.9 sp. gr., by 10 per cent salt-solution (analysis of preparation **15** under V., table), and that dissolved out by dilute potash (analysis of preparation **16** under V *a*), have so nearly the same composition as the globulin extracted by salt-solution directly that they may be regarded as originally identical, IV representing the soluble form, V and V *a* the insoluble or "albuminate" modification. (See pp. 68–71).

6. When ground oats are directly extracted by alkali-solutions, without previous treatment with water or dilute alcohol, nearly the whole of the proteids is dissolved. The substance so extracted, after completely removing the body soluble in weak alcohol, is perhaps the same as that first designated *avenine* by Johnston and Norton, who extracted oats with dilute ammonia-water. Its composition is stated under VI and VI *a*. (See also pp. 71–72).

7. When ground oats are exposed to the action of water, a large share of the proteids becomes insoluble in dilute potash solution, the amount so rendered insoluble increasing with the duration of the contact with water. One hour's treatment with water rendered one-half, twenty-four

*The numbers of the paragraphs in this summary correspond with the numbers over the analyses in the table following.

†*Vide* p. 57.

hours' treatment made two-thirds insoluble in two-tenths per cent solution of potash. The composition of the part soluble in potash, after action of water (and removal of the alcohol-soluble proteid), as found in analyses of preparations **18** and **19**, the average of which is stated under VII, table, is the same as that of the globulin soluble in salt-solution IV. This proteid, obtained by extraction with potash, *after* the action of water, is probably the substance which Kreusler converted into his *Oat-Legumin* by the "purifying" process to which he subjected it. It is also the "protein body" which Norton extracted by weak ammonia and analyzed. (See pp. 72–76).

8. When ground oats are extracted with 10 per cent sodium chloride solution heated to 65° C., a proteid separates on cooling in the form of spheroids. This substance differs in composition and properties from that obtained by cold salt extraction, as well as from all proteids hitherto described. It is soluble in pure water, precipitated from such solutions by a little sodium chloride, is again dissolved by a certain additional quantity, and is precipitated completely by saturation with this salt. In the presence of a little sodium chloride and acetic acid it is soluble in alcohol of 0.9 sp. gr. From solutions in distilled water, as well as from those in sodium chloride brine, it has been obtained crystallized in regular octahedra. Analysis (of spheroids) under VIII. (See pp. 76–78).

9. When the "albuminate" form of the globulin is dissolved in sodium carbonate solution and precipitated by carbonic acid or by ammonium sulphate, and the resulting precipitate dissolved in 10 per cent sodium chloride solution and dialyzed, a globulin separates in spheroids having the properties and composition of the globulin extracted by hot sodium chloride solution analysis under IX. (See pp. 78–80).

10. When the globulin described in 9 is dissolved in warm 2 per cent sodium chloride solution it separates on cooling in distinct crystals. Analysis under X. (See pp. 80–82).

11. When ground oats are directly extracted with weak sodium carbonate solution, the extract saturated with ammonium sulphate, the resulting precipitate extracted with 10 per cent sodium chloride solution and this extract dialyzed, the same globulin is obtained, analysis of which is given in the table under XI. (See p. 82.)

12. The aqueous extract of ground oats was found, in agreement with Norton and Kreusler, to contain very little proteid substance. The proteids thus dissolved appear to be, first, an *acid-albumin*; second, *globulin* or *globulins* similar in reactions to that extracted by 10 per cent salt-solution, and third, a *proteose*. No true albumin was found in the water extract. (See pp. 63–65.)

13. In the salt extract a very small amount of a body was found, having the reactions of *albumin*, but not analyzed (pp. 65–66).

Table of composition of proteids from the oat-kernel.

	I.	II.*	III.*	IV.	V.	V *a*.	VI.	VI. *a*	VII.*	VIII.	IX.	X.*	XI.
Carbon	53.06	53.10	53.70	52.34	52.48	52.45	53.49	53.63	52.49	52.22	52.30	52.18	51.82
Hydrogen	6.94	6.91	7.00	7.21	6.94	6.92	7.01	7.18	7.10	6.98	6.98	7.05	6.93
Nitrogen	16.38	16.49	15.71	16.88	16.85	16.63	16.39	16.11	17.11	17.85	17.86	17.90	17.95
Sulphur	2.26	(23.50)	1.76	0.88	0.57	0.81	0.99	0.82	0.80	0.77	0.69	0.53	(23.30
Oxygen	21.36		21.83	22.69	23.16	23.19	22.12	22.26	22.50	22.18	22.17	22.34	
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Average of several analyses.

XIV.—Conclusion.

The proteids of the oat kernel undergo great change in contact with water or sodium chloride solution. The body extracted by direct treatment of ground oats with alcohol differs much in properties and composition from that extracted by alcohol after the ground oats have had contact for some time with water or sodium chloride solution.

Direct treatment with sodium carbonate solution yields the same globulin as that obtained by direct treatment with hot sodium chloride solution, but a different globulin from that obtained by direct treatment with cold sodium chloride solution. Sodium carbonate solution also extracts another proteid, the same as that yielded by direct extraction with dilute potash lye, which again

is distinct in composition from that obtained after the oats have been in contact with water. It is remarkable that all these transformations are the result of the use of water or salt solution as contrasted with the use of alcohol, alkali, or heat, three agents known to suspend or destroy ferment action. The fact that the globulin extracted after treatment of the ground oats with alcohol has the same composition as that obtained by direct treatment with sodium chloride, would indicate that alcohol temporarily suspends a ferment action, which is induced by water or solutions of neutral salts. It is probable that the primary proteids originally contained in the oat kernel are the three following bodies:

Primary oat proteids.

	Alcohol soluble proteid. Average of 5 analyses.	Salt soluble proteid or globulin. Average of 9 analyses.	Alkali soluble proteid. Average of 2 analyses.
Carbon	53.01	52.19	53.56
Hydrogen	6.91	7.00	7.09
Nitrogen	16.43	17.86	16.20
Sulphur	2.26	0.65	0.90
Oxygen	21.39	22.30	22.25
	100.00	100.00	100.00

Of the above substances the alcohol soluble proteid forms about one and a quarter per cent, the globulin about one and a half per cent, and the alkali soluble body the remainder of the proteids contained in the oat kernel, with the possible exception of extremely small amounts of proteose and acid albumin. The two latter substances are quite probably the results of change occurring during extraction; the evidence, however, on this point is not conclusive.

Three other proteids are obtained, evidently by the alteration of the primary proteids, and probably through ferment action if the ground oats are subjected to contact with water or solutions of neutral salts. The composition of these derived or secondary proteids is as follows:

Secondary oat proteids.

	Alcohol soluble proteid (average of 4 analyses).	Salt-soluble proteid or globulin (average of 4 analyses).	Alkali soluble proteid (average of 2 analyses).
Carbon	53.70	52.34	52.49
Hydrogen	7.00	7.21	7.10
Nitrogen	15.71	16.88	17.11
Sulphur	1.76	0.88	0.80
Oxygen	21.83	22.69	22.50
	100.00	100.00	100.00

It would appear that none of the proteids from the oat kernel have hitherto been obtained in a state of purity. The author therefore reserves the right to revise the nomenclature of these bodies after further progress in his researches on the other vegetable proteids with which he is now engaged.

LABORATORY OF THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION,
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NATIONAL ACADEMY OF SCIENCES.

VOL. VI.

FIFTH MEMOIR.

A COMPARISON OF ANTIPODAL FAUNAS.

A COMPARISON OF ANTIPODAL FAUNAS.

By Theodore Gill.

(Read November, 1887.)

PREFATORY.

I.

A comparison of antipodal faunas, it was thought, might reveal the salient characteristics of such, independent of climatic considerations, and none were better fitted for the purpose of study than the piscine inhabitants of the British islands on the one hand and the New Zealand waters on the other. Both groups of islands agree approximately in size and the temperature of the waters. The difference in the distances from neighboring lands introduces, it is true, another factor, but, far from being the cause of embarassment, it might tend to throw light on the subject. For these reasons a comparison was instituted between the regions in question.

The British fishes have been quite recently fully described and illustrated, and our knowledge of the subject, so far at least as specific diversities are concerned, has been nearly brought up to date by Surgeon Francis Day in his "Fishes of Great Britain and Ireland." A summary of the families and including orders, as understood by the present writer, has also been given in a comparison of the faunas of the British islands and Massachusetts in the Report of the Smithsonian Institution for 1883.

The New Zealand fishes, at time of presentation of this memoir, had not been collected in any nomenclator (the last published list of the species having appeared in 1872), and the abundant literature on the subject, whereby the number of species had been nearly doubled, was scattered through many volumes. It was necessary, therefore, to bring together and consult the numerous articles in which the information was embodied. Since then a very useful and ably compiled "List of the New Zealand Fishes" has been issued by Prof. J. W. Hutton, long and favorably known for his researches on the fishes as well as many other animals of the colony. A number of the changes made in the original memoir have thereby been anticipated and others have been meanwhile forestalled by European naturalists.* Nevertheless, there is still much to be done in clearing up doubts respecting many species, and numerous changes have been made in the memoir, as now published, which appear to be justified by evidence now at hand. A point will be gained if renewed attention is directed to questions here raised, and science will be the beneficiary, whether the conclusions now enunciated are verified or falsified.

*Among the rectifications which would have been the first to appear in the memoir, if it had been published soon after the date of presentation, were new generic names for those since called *Plagiogenion*, *Neptotichthys*, and *Ancheroceros*, the elimination of *Ctenolabrus knoxi* from the *Labrinæ* and its association, in common with *Pimelepterus dreuii* and *Girella percoides*, with *Girella simplex*, and the rectification of the synonymy of the Uranoscopids and Leptoscopids, on the basis established by Prof. Hutton. The anticipation is, however, compensated for by finding that I had independently reached the same conclusions as that excellent naturalist.

II.

PREVIOUS CATALOGUES OF NEW ZEALAND FISHES.

The fishes of few countries have been studied with more zeal and ability (so for as mere specific characters are concerned) than have those of New Zealand by resident naturalists. Some of the species of that group were among the first known of the southern hemisphere, and of no region of that hemisphere are the fishes now better known. Six catalogues of the species have appeared viz:

1. JOHANN REINHOLD FORSTER.

§ 1.

M. E. Blochii, ..., Systema Ichthyologiae iconibus CX illustratum.—Post obitum auctoris opus inchoatum absolvit correxit, interpolavit Io. Gottlob Schneider, Saxo.—Berolini, ... 1801.

In this work were first published from the MSS. of Forster his descriptions of new species.

§ 2.

Descriptiones Animalium quæ in itinere ad maris australis terras per annos 1772 1773 et 1774 suscepto collegit observavit et delineavit Ioannes Reinhold Forster. . . nunc demum editae auctoritate et impensis academiae litterarum regiae Berolinae curante Henrico Lichtenstein ..... Berolini ex officina academica. MDCCCXLIV.—Vendit Dummleri libraria. [8vo, xiii (1 l.) + 424 pp.]

In this work, Forster's descriptions are given approximately in the order in which they were made on the spot, and consequently they are brought together under two periods when Cook visited New Zealand during his second voyage, viz: March, May, and June, 1773 (pp. 112–148), and October, 1774 (pp. 301–310). 31 species were described.

2. DR. JOHN RICHARDSON.

§1.

Report on the present state of the Ichthyology of New Zealand. By John Richardson, M. D., F. R. S., etc., Inspector of Naval Hospitals, at Haslar. <Report of the twelfth meeting of the British Association for the Advancement of Science; held at Manchester in June, 1842, (pp. 12–30, 1843).

This contains 91 species arranged according to the classification of Cuvier.

§ 2.

List of fish hitherto detected on the coasts of New Zealand, by John Richardson, M. D., Inspector of Hospitals at Haslar; with the descriptions, by J. E. Gray, Esq., and Dr. Richardson, of the new species brought home by Dr. Reichenbach. <Travels in New Zealand; with contributions to the Geography, Geology, Botany, and Natural History of that country. By Ernest Dieffenbach, M. D., (vol. II, pp. 206–228, 1843).

The second edition of Richardson's report contains 92 nominal species, the addition to the former list being "(85) *Carcharias* (*Prionodon*) *mavo* Müller and Henle." Long descriptions of "(51) *Hemerocœtes acanthorhynchus* C. and V." "(62) *Hemirhamphus marginatus* Lacépède," and "(73) *Rhombus plebius* Solander" are added. The descriptions are by Richardson, the only justification for the claim of "descriptions by J. E. Gray, Esq., and Dr. Richardson" being the incorporation of the brief notices of *Galaxias fasciatus* and *Anguilla Dieffenbachii* by Gray, originally published in his "Zoölogical Miscellany." There are various minor differences between the two catalogues. Several species admitted were not entitled to a place in the New Zealand fauna.

3. PIETER BLEEKER.

Over eenige Visschen van Van Diemensland. Door Dr. P. Bleeker te Batavia. Uitgegeven door de Koninklijke Akademie van Wetenschappen.....Amsterdam C. G. Van der Post. 1855. [4to, title + 31 pp., 1 folded pl.]

This memoir was prefaced by a comparative enumeration of the fishes of (1) Australia or "Nova Hollandia," (2) New Zealand, (3) Tasmania or Van Diemensland, (4) Norfolk island, and

(5) Auckland islands, and (6) the distribution of Australasian fishes beyond Australasia ("extra-Australasiatici"). The numbers of species attributed to the respective regions were as follows:

Nova Hollandia	236
Nova Zelandia	71
Diemenia	70
Insula Norfolkiæ	8
Insula Aucklandiæ	5
Extra-Australasiatici	103

Dr. Bleeker did not display in this memoir his usual familiarity with the literature, and manifested no acquaintance with the articles of Richardson on the fishes of New Zealand. Many of Forster's fishes were also overlooked.

4. Frederick Wollaston Hutton (1).

Fishes of New Zealand. Catalogue, with diagnoses of the species. By Frederick Wollaston Hutton, Notes on the edible fishes, by James Hector, M. D. ...., Wellington.—1872. [8vo, xvi, 133, ii pp., 12 pl., iii pp.]

141 native and 7 introduced species were described and 49 illustrated by outline figures on 12 plates.

5. R. A. A. Sherrin.

Handbook of the fishes of New Zealand.—Prepared under the instructions of the Commissioner of Trade and Customs by R. A. A. Sherrin.—Auckland: Wilsons and Horton.—MDCCCLXXXVI. [8vo, 2 pl., iv, pp. 307, 1 folded map.]

A dictionary (pp. 9—128, 129—143) in which the principal (1) salt-water and (2) fresh-water species are noticed under their English names in alphabetical order, and a "List of Fishes of New Zealand" (pp. 298-307), are the chief features of the "Handbook." The work is that of a compiler and not of an original investigator, and as such is as reliable as could be reasonably expected.

6. Frederick Wollaston Hutton (2).

List of the New Zealand fishes. By Professor F. W. Hutton. <Trans. N. Z. Inst, vol. xxii, pp. 275-285, 1889.

The list enumerates 226 species, "the arrangement followed being that of Dr. Günther's 'Study of Fishes.'" References are given "which show the evidence for the species being included in the list." It is a valuable and well-considered summary of what had been made known up to the date of publication.

III.

THE FORSTERIAN FISHES OF NEW ZEALAND.

I.

The first glimpse of the piscine fauna of New Zealand is due to Dr. John Reinhold Forster, who accompanied the celebrated Capt. Cooke on his second voyage, and visited New Zealand in 1773 and again in 1774. Forster made full descriptions, and his son George drew sketches of many fishes observed by him and gave them scientific names, but his own work embodying these observations remained unpublished for nearly three-quarters of a century. Meanwhile, however, Forster's manuscripts fell into the hands of Schneider, the editor and completer of Bloch's "Systema Ichthyologiæ," and the new species of fishes were incorporated in the "Systema" generally with Foster's own names, but in some cases with new ones.

II.

The New Zealand fishes credited to Forster in the "Systema" were as follows; (1) the numbers in the left-hand column indicating the pages; (2) the names in the second column being those of Forster and Schneider, and (3) the names in the right-hand column being those for the present adopted.

SYSTEMA ICHTHYOLOGIÆ.

	Old names.	*Present names.*
2	Lepadogaster pinnulatus F	Trachelochismus pinnulatus.
24	Scomber dentatus F	Thyrsites atun.
37	Scomber punctatus F. B. S. / Gasterosteus punctatus F.	Scriolella ?? punctata.
41	Callionymus monopterygius B. S. / Callionymus acanthorhynchus F.	Hemerocoetes acanthorhynchus.
49	Uranoscopus monopterygius B. S. / Uranoscopus maculatus F.	Genyagnus maculatus.
53	Enchelyopus bachus B. S., F	Pseudophycis bacchus.
54	Enchelyopus colias B. S., F	Parapercis colias.
56	Phycis tinca, var. B. S. / Gadus rhacinus F.	Lotella rhacina.
120 XXXII	Mugil albula Forsteri	Agonostomus forsteri.
121 XXXII	Mugil salmoneus F	Chanos salmoneus.
163	Pleuronectes scapha F	Caulopsetta scapha.
173	Blennius fenestratus F	Notoclinus fenestratus.
174 XXXVI	Blennius tripennis * F	Tripterygion tripinne.
177	Blennius quadridactylus B. S. / Blennius litoreus F.	Acanthoclinus litoreus.
178	Blennius varius F	Tripterygion varium.
196	Synaneeia papillosus B. S.† / Scorpaena cottoides F.	Sebastapistes cottoides.
199	Cyclopterus littoreus F	Trachelochismus litoreus.
264	Labrus miles B. S. / Labrus coccineus F.	Pseudolabrus miles.
265	Labrus celidotus F	Pseudolabrus celidotus.
266	Labrus auratus B. S. / Sciaena aurata F.	Pagrosomus auratus.
288	Scarus pullus B. S. / Sparus pullus F.	Coridodax pullus.
301	Epinephelus oxygeneios B. S. / Perca prognatha F.	Polyprion prognathus.
302	Epinephelus lepidopterus B. S. / Perca lepidopterus F.	Pseudanthias lepidopterus.
310	Anthias ciliaris B. S. / Sciaena ciliaris F.	Latris ciliaris.
342	Cichla lineata B. S. / Sciaena lineata F.	Latris lineata.
342	Cichla macroptera B. S. / Sciaena macroptera F.	Cheilodactylus macropterus.
394	Esox saurus (L.) F	Scomberesox forsteri.
395	Esox alepidotus (F.)	Galaxias alepidotus.
477	Balistes scaber F	Monacanthus scaber.
484	Ophidium blacodes B. S.‡	Genypterus blacodes.
532	Petromyzon cirrhatus F	Heptatrema citrata.
542	Sciaena trutta F	Arripis trutta.

III.

Forster's new work (Descriptiones Animalium, etc.) was not published till 1844, when it appeared (without the illustrations) under the editorship of Lichtenstein at Berlin. The descriptions and notes on the animals observed were arranged in a rough, chronological order, that is, nearly under the dates when the species were observed and described, but with some slight deviations therefrom.

* Not tripinnis, as it should have been written.

† P. xxxvii, "*Pertinet ad Genus antecedens*" [*i. e., Scorpaena*].

‡ Forster's *name* is not mentioned in connection with *O. blacodes*, which is also noticed from the Cape of Good Hope, as well as New Zealand.

FORSTER'S DESCRIPTIONES ANIMALIUM.

(1773—Apr. 8.)

112....Petromyzon cirrhatus.....Heptatrema cirrata.

(1773—Apr. 7.)

114....Cyclopterus littoreus.....Trachelochismus litoreus.

(1773—Apr. 13.)

115....Ophidium blacodes.....Genypterus blacodes.
117....Callionymus acanthorhynchus.....Hemerococtes acanthorhynchus.
118....Uranoscopus maculatus.....Genyagnus maculatus.
120....Gadus bacchus.....Pseudophycis bacchus.

(1773—Mart. 27.)

122....Gadus colias.....Parapercis colias.

(1773—Maii. 27.)

124....Blennius fenestratus.....Notoclinus fenestratus.

(1773—April 9.)

125....Blennius tripennis.....Tripterygion tripinne.

(1773—April 7.)

127....Blennius littoreus.....Acanthoclinus litoreus.

(1773—Iun. 4.)

127....Blennius varius.....Tripterygion varium.

(1773—Mart. 30.)

128....Scorpaena cottoides.....Sebastapistes cottoides.
130....Pleuronectes scapha.....Canlopsetta scapha.
131....Labrus coccineus.....Pseudolabrns miles.
133....Labrus celidotus.....Pseudolabrus celidotus.
134....Sciaena lineata.....Latris lineata.
136....Sciaena macroptera.....Cheilodactylus macropterus.
137....Sciaena ciliaris.....Latris ciliaris.
138....Perca lepidoptera.....Pseudanthias lepidoptera.
140....Gasterosteus punctatus.....Scriolella ?? punctata.
141....Scomber dentex.....Thyrsites atun.
142....Esox alepidotus.....Galaxias alepidotus.
143....Esox saurus.....Scomberesox forsteri.
145....Mugil albula.....Agonostomus forsteri.
147....Sciaena trutta.....Arripis trutta.
152....Balistes scaber.....Monacanthus scaber.

(1774—Octobr. 10.)
Norfolk Island.

292....Sciaena cultrata.....Bathystethus cultratus.

(1774—Octobr. 23.)

301....Cyclopterus pinnulatus.....Trachelochismus pinnulatus.

(1774—Octobr. 29.)

304....Gadus rhacinus.....Lotella rhacina.

(Octobr. 28.)

306....Sparus pullus.....Coridodax pullus.

(Octobr. 18.)

307....Sciaena aurata.....Pagrosomus auratus.

(Octobr. 15.)

309....Perca prognathus.....Polyprion prognathus.

IV.

It is to be remarked that some of the species described by Forster have each received two names, Schneider, with the propensity common in his time to change a name because it did not seem to be as good a one as could be given, substituting for Forster's one of his own which suited him better. Nevertheless Forster's, in every case but one,* was also given. Forster's names were therefore actually *published* at the same time as Schneider's and in connection with his (Forster's) own descriptions. Whose names then shall be adopted, Forster's or Schneider's? Opinion has differed as to this point, some accepting Forster's and others Schneider's.

Ophidium blacodes was Forster's name, but not accredited to him, and Schneider had seen a specimen of the species from the Cape of Good Hope.

Cuvier and Valenciennes sometimes adopted Forster's*, and sometimes (the propensity to change names still continued) gave new ones, because, for some reason or other, they were not satisfied with any of the old ones†.

Richardson‡ also generally adopted Forster's names§, deviating from this course only in four instances, once in adopting one of Schneider's names‖, again in preferring a manuscript name given by Solander to one published by Forster¶, a third time in taking a later name of Lacépède**, and, in another case, deferring to Cuvier and Valenciennes††.

Günther generally accepted Forster's names, but in one instance adopted Schneider's‡‡, and for other species took later names.

The Güntherian nomenclature was adopted by Prof. Hutton and Prof. Hector in the Catalogue of the Fishes of New Zealand, and the names so adopted are given in the synonymy of the species following. Later, Prof. Hutton revived several of Forster's names previously generally neglected.

As the conflicting names of Forster and Schneider were necessarily published at the same moment, being each printed for the first time on the same page, neither has the priority, and the name adopted by the first succeeding naturalist may, I think, be justly retained. Drs. Jordan and Eigenmann have thought otherwise, and, in the case of *Polyprion*, adopted Schneider's name *oxygeneios* instead of *prognathus*, but as Drs. Jordan and Gilbert had originally used that name for the "*P. cernium*," the southern species may retain that of *P. prognathus* later given to it. Drs. Jordan and Gilbert, in another connection (involving the question of adoption of *Cephalacanthus* or *Dactylopterus*, the former occurring on p. 323 and the latter on p. 325 of the same work), have declared for *Cephalacanthus* instead of the generally adopted *Dactylopterus*, and enunciated the proposition that "the law of primogeniture applies to twins"§§. This is granted. But what has the law of primogeniture to do with the question at issue? In the case of twins, as the learned doctors well know, one always precedes the other by an appreciable interval of time, but in the case of two names first printed on the same signature, the *publication* of the two is necessarily *simultaneous*, and no question of primogeniture can arise. Under the present circumstances, then, the adoption of one or the other name is open to the next naturalist who has to deal with the species, and I shall follow him. My own preference would be to adopt Forster's names, as he was the original investigator and generally his names were more apt, but, it seems to me, the name to be used was fixed by the action of the first user.

HEPTATREMIDÆ.

Heptatrema cirrata.‖‖

Petromyzon cirrhatus *Bloch* and *Schneider*, Systema Ich., p. 532, 1801; *Forster*, Desc. Animal. cur. Lichtenstein, p. 112, 1844.

Heptatrema dombeyi *Richardson*, Rep. Br. A. A. S., 1842, p. 30.

Bdellostoma cirrhatum *Hutton*, Fishes New Zealand, p. 87, 1872 (1889, No. 223).

Habitat in mari alluente insulam australem Novae Zcelandiae, in portu obscuro et in Aestuario Reginae Charlottae.—F.

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*(1) *Centropristes trutta* (2, 54)=*Sciaena trutta* F.; (2) *Percis colias* (3, 273)=*Gadus colias* F.; (3) *Clinus littoreus* (11, 389)=*Blennius littoreus* F.; (4) *Tripterygion fenestratum* (11, 410)=*Blennius fenestratus* F.; (5) *T. varium* (11, 414)=*B. varius* F.; (6) *Hemerocoetes acanthorhynchus* (12, 311)=*Callionymus acanthorhynchus* F.; (7) *Odax pullus* (14, 304)=*Scarus pullus* F.

†(1) *Polyprion cernium* (3, 21)=*Perca prognatha*, F.=*Epinephelus oxygeneios*; (2) *Uranoscopus forsteri* (3, 318)=*U. maculatus* F.=*U. monopterygius* B. S.; (3) *Tripterygion forsteri* (11, 415)=*Blennius tripennis* F.

‡Rep. 12. meet. Brit. A. A. S., pp. 12-30, 1843; Dieffenbach's Travels in N. Z., vol. 2. pp. 206-228, 1843.

§*Serranus lepidopterus, Centropristes trutta, Percis colias, Uranoscopus maculatus, Scorpæna cottoides, Cheilodactylus macropterus, Latris lineata, L. ciliaris, Clinus littoreus, Tripterygion varium, T. fenestratum, Hemerocoetes acanthorhynchus, Julis celidotus, Odax pullus, Galaxias alepidotus, Lota baccha, Lota rhacina, Rhombus? scapha, Lepadogaster pinnulatus, Gobiesox littoreus, Ophidium blacodes, Monacanthus scaber.*

‖*Julis miles*=*Labrus miles* B. S.=*L. coccineus* F.

¶*Heptatrema dombeyi* (ex Lac.) = *Petromyzon cirrhatus* F.

**Pagrus latus* (Rich. Annals, IX, p. 392) = *Sciæna lata* Sol. in place of *Sc. aurata* F.

††*Tripterygion forsteri* (C. V.) = *Blennius tripennis* F.

‡‡*Anema monopterygium* (2, 230) = *Uranoscopus monopterygius* B. S.= *U. maculatus* F.

§§Proc. U. S. Nat. Mus., Vol. V, p. 573.

‖‖Omni vel specie rectae rationis, qui *Pleurotomam* similiaque vocabula neutralis generis habent. Conferatur *περιτομός*." Hermannsen, Indicis Generum Malacozoorum Primordia, vol. I, 1846, p. XIII.

GALAXIIDÆ.

Galaxias alepidotus.

Esox alepidotus *Bloch and Schneider*, Syst. Ich., p. 395, 1801; *Forster*, Desc. Animal. cur. Lichtenstein, p. 142, 1844.

Galaxias alepidotus *Hutton*, Fishes New Zealand, p. 58, 1872

Habitat in lacubus aquae dulcis et rivulis insulae australis Novae Zeelandiae, hamo captus. Sapidus et a nautis vocatus *trutta* (the trout).—F.

EXOCOETIDÆ.

Scomberesox forsteri.

Esox saurus (*Lac.*) *Bloch* and *Schneider*, Syst. Ich., p. 391, 1801; *Forster*, Desc. Animal. cur. Lichtenstein, p. 143, 1844.

Scombresox forsteri (*Cur. and Val.*) *Hutton*, Fishes New Zealand, p. 53, 1872.

Habitat in mari alluente Novam Zeelandiam; semper post tempestuosum tempus a mari in littus ejectus repertus.

MUGILIDÆ.

Agonostomus forsteri.

Mugil albula Forsteri *Bloch* and *Schneider*, Syst. Ich., p. xxxii, 120, 1801.

Mugil albula *Forster*, Desc. Animal. cur. Lichtenstein, p. 115, 1844.

Mugil fosteri *Cur. and Val.*, Hist. Nat. Poissons, Vol. 11, p. 141.

Agonostoma forsteri *Hutton*, Fishes New Zealand, p. 37, 1872 (1889, No. 124).

Habitat in mari alluente insulam australem Novae Zeelandiae.—F.

Schneider, to whom the name *forsteri* is generally attributed, merely recorded it as the *Mugil albula* of Forster; Cuvier and Valenciennes gave the specific name *forsteri*.

Dr. Günther (Vol. III, p. 461) has needlessly changed the name *Agonostomus* (Bennett, P. Z. S., 1830, p. 166) to *Agonostoma*, although he later retained the spelling of the analogous names *Plecostomus* (Vol. V, p. 230), *Chætostomus* (Vol. V, p. 240), *Andstomus* (Vol. V, p. 303), etc.

CARANGIDÆ.

Seriolella ?? punctata ?

Scomber punctatus = Gasterosteus punctatus *Bloch* and *Schneider*, Syst. Ich., p. 37, 1801.

Gasterosteus punctatus *Forster*, Desc. Animal. cur. Lichtenstein, p. 110, 1844.

Habitat in mari alluente insulam australem Novae Zeelandiae, hamo captus, at non fundo, vero in media regione, locis tranquillis, prope rivulos aquae dulcis; nautis Scomber (*Mackrel*) dictus.—F. Mart. 30, 1773.

Like others I have been unable to identify the *Gasterosteus punctatus* F. Most authors have quietly ignored it. It is only referred to by Prof. Hutton (Trans. N. Z. Inst., vol. IX, p. 353).

GEMPYLIDÆ.

Thyrsites atun.

Scomber dentatus (F.) *Bloch* and *Schneider*, Syst. Ich., p. 24, 1801.

Scomber dentex *Forster*, Desc. Animal. cur. Lichtenstein, p. 141, 1844.

Thyrsites atun *Hutton*, Fishes New Zealand, p. 13, 1872.

Habitat in mari, insulam australem Novae Zeelandiae alluente.—F.

The species had been previously described by Euphrasen as *S. atun*.

SPARIDÆ.

Pagrosomus auratus.

Labrus auratus (=Sciæna aurata, F.) *Bloch* and *Schneider*, Syst. Ich., p. 266, 1801.

Sciæna aurata *Forster*, Desc. Animal. cura Lichtenstein, p. 307, 1844.

Pagrus latus *Rich.*, Rep. Br. A. A. S., 1842, p. 209.

Pagrus unicolor *Hutton*, Fishes New Zealand, p. 6, 1872.

Habitat in Aestuario Reginae Charlottae, in Nova Zeelandia.—F.

The specific name *auratus*, being the first given, should be adopted, and as the species differs from the Spari and Pagri by the obsolescence of the inner lateral cranial crests, the new generic name *Pagrosomus* may be given.

ARRIPIDIDÆ.

Arripis trutta.

Sciæna trutta (F.) *Bloch* and *Schneider*, Syst. Ich., p. 394, 1801; *Forster*, Desc. Animal. cura. Lichtenstein, p. 147, 1844.
Centropristes trutta *Richardson*, Rep. Br. A. A. S., 1842, p. 15.
Centropristes mulloides *Richardson*, Rep. Br. A. A. S., 1842, p. 16.
Centropristes sapidissimus *Richardson*, Rep. Br. A. A. S., 1842, p. 16.
Arripis salar *Hutton*, Fishes New Zealand, p. 2, 1872.

Habitat in mari alluente Fretum Cookii et intrante Aestuarium Reginae Charlottae.—F.

SERRANIDÆ.

Pseudanthias lepidopterus.

Epinephelus lepidopterus (=Perca lepidoptera F.) *Bloch* and *Schneider*, Syst. Ich., p. 302, 1801.
Perca lepidoptera *Forster*, Desc. Animal. cur. Lichtenstein, p. 138, 1844.
Serranus lepidopterus *Rich.*, Rep. Br. A. A. S. 1842, p. 15.
Scorpis hectori *Hutton*, Fishes New Zealand, p. 4, 1872.

Habitat in mari alluente insulam australem Novae Zeelandiae.—F

Polyprion prognathus.

Epinephelus oxygenios (=Perca prognatha F.) *Bloch* and *Schneider* Syst. Ich., p. 301, 1801.
Perca prognathus *Forster* Desc. Animal. cur. Lichtenstein, p. 309, 1844.
Oligorus gigas *Hutton* Fishes New Zealand, p. 1, 1872.
Polyprion prognathus *Günther* Ann. Mag. Nat. Hist. (5.), vol. xx, p. 236, 1887.

Habitat in Aestuario Reginae Charlottae.—F.

The identity of *Oligorus gigas* and *Perca prognathus* was first recognized by Prof. Hutton, (Trans. N. Z., Inst., Vol. v, p. 259), but, influenced by undue respect for the opinion of Dr. Günther, he retained it in the genus *Oligorus* instead of restoring it to the genus *Polyprion*, to which Cuvier and Valenciennes, with their superior knowledge, had previously properly referred it.

LABRIDÆ.

Pseudolabrus miles.

Labrus miles (=L. coccineus F.) *Bloch* and *Schneider* Syst. Ich., p. 261, 1801
Labrus coccineus *Forster* Desc. Animal. cur. Lichtenstein, p. 131, 1844.
Julis miles *Rich.* Rep. Br. A. A. S., 1843, p. 24, 1843.
Labrichthys psittacula *Hutton* Fishes New Zealand, p. 43, 1872.

Habitat in mari alluente insulam australem Novae Zeelandiae.—F

Pseudolabrus celidotus.

Labrus celidotus (F) *Bloch* and *Schneider* Syst. Ich. p. 265, 1801.
Labrus celidotus *Forster* Desc. Animal. cur. Lichtenstein, p. 133, 1844.
Julis celidotus *Rich.* Rep. Br. A. A. S., 1842, p. 24, 1843.
Pseudolabrus celidotus *Bleek.* Versl. en Med. K. Akad. Wett. (Amsterdam), Vol. xv, p. 444, 1863.
Labrichthys celidota *Hutton* Fishes New Zealand, p. 42, 1872.

Habitat in mari alluente insulam australem Novae Zeelandiae.—F.

Coridodax pullus.

Scarus pullus (=Sparus pullus F.) *Bloch* and *Schneider* Syst. Ich., p. 288, 1801.
Sparus pullus *Forster* Desc. Animal. cur. Lichtenstein, p. 306, 1844.
Odax pullus *Cuv. et Val.* Hist. Nat. Poiss., vol. xiv, p. 304.
Coridodax pullus *Hutton* Fishes New Zealand, p. 44, 1872.

Habitat in Aestuario Reginae Charlottae in Nova Zeelandia.—F.

HAPLODACTYLIDÆ.

Chilodactylus macropterus.

Cichla macroptera (=Sciæna macropt. F.) *Bloch and Schneider* Syst. Ich., p. 342, 1801.
Sciæna macroptera *Forster* Desc. Animal. cur. Lichtenstein, p. 136, 1844.
Cheilodactylus macropterus *Rich.* Trans. Zool. Soc., Vol. III, p. 101.
Chilodactylus macropterus *Hutton* Fishes New Zealand, p. 8, 1872.

Habitat in mari Novae Zeelandiae insulam australem alluente. —F.

Latris ciliaris.

Anthias ciliaris (=Sciæna ciliaris F.) *Bloch and Schneider* Syst. Ich., p. 310, 1801.
Sciæna ciliaris *Forster* Desc. Animal. cur. Lichtenstein, p. 137, 1844.
Latris ciliaris *Rich.* Trans. Zool. Soc., Vol. III, p. 115.
Latris ciliaris *Hutton* Fishes New Zealand, p. 9, 1872.

Habitat in mari alluentem insulam australem Novae Zeelandiae.—F.

Latris lineata.

Cichla lineata (=Sciæna lineata F.) *Bloch and Schneider* Syst. Ich., p. 342, 1801.
Sciæna lineata *Forster* Desc. Animal. cur. Lichtenstein, p. 134, 1844.
Latris hecateia *Rich.* Trans. Zool. Soc., Vol. III, p. 106, pl. 6, f. 1 (see p. 115).
Latris hecateia *Hutton* Fishes New Zealand, p. 8, 1872.

Habitat in mari alluente insulam australem Novae Zeelandiae.—F.

SCORPÆNIDÆ.

Scorpæna cottoides.

Synanceja papillosus (sic!=Scorpæna cottoides F.) *Bloch and Schneider* Syst. Ich., p. 196, 1801.
Scorpæna papillosa *Bloch and Schneider* Syst. Ich., p. XXXVII, 1801.*
Scorpæna cottoides *Forster* Desc. Animal. cur. Lichtenstein, p. 128, 1844.
Scorpæna cottoides *Rich.* Rep. Br. A. A. S., p. 18, 1843.
Scorpæna cruenta *Hutton* Fishes New Zealand, p. 10, 1872.

Habitat in mari alluente Novam Zeelandiam.—F.

URANOSCOPIDÆ.

Genyagnus maculatus.

Uranoscopus monopterygius (=Uranoscopus maculatus F.) *Bloch and Schneider* Syst. Ich., p. 49, 1801.
Uranoscopus maculatus *Forster* Desc. Animal. cur. Lichtenstein, p. 118, 1844.
Uranoscopus maculatus *Rich.* Ann. Nat. Hist., Vol. IX, p. 207.
Kathetostoma monopterygium *Hutton* Fishes New Zealand, p. 23, 1872.

Habitat in australe insula Novae Zeelandiae [etc.].—F.

PERCOPHIDÆ.

Parapercis colias.

Enchelyopus colias (= G. C., F.) *Bloch and Schneider* Syst. Ich., p. 54, 1801.
Gadus colias *Forster* Desc. Animal. cur. Lichtenstein, p. 122, 1844.
Percis colias *Cur. et Val.* Hist. Nat. Poiss, Vol. III, p. 273. *Hutton* Fishes New Zealand, p. 25, 1872.

Habitat in mari alluente insulam australem Novae Zeelandiae [etc.].—F.

HEMEROCŒTIDÆ.

Hemerocœtes acanthorhynchus.

Callionymus monopterygius (=Callionymus acanthorhynchus) *Bloch and Schneider* Syst., Ich., p. 41, 1801.
Callionymus acanthorhynchus *Forster* Desc. Animal. cur. Lichtenstein, p. 117, 1844.
Hemerocœtes acanthorhynchus *Cur. et Val.* Hist. Nat. Poiss., Vol. XII, p. 311. *Hutton* Fishes New Zealand, p. 37, 1872.

Habitat in mari alluente insulam australem Novae Zeelandiae.—F.

* Scorpæna "10, Papillosa Forsteri. (Male ad sequens genus [*i. e. Synanceia*] relata.)"—p. XXXVII.

CLINIDÆ.

Notoclinus fenestratus.

Blennius fenestratus (F.) *Bloch and Schneider* Syst. Ich., p. 173, 1801; *Forster* Desc. Animal. cur. Lichtenstein, p. 124, 1844.
Tripterygion fenestratum *Cuv. et Val.* Hist. Nat. Poiss., Vol. XI, p. 410; *Hutton* Fishes New Zealand, p. 0, 1872 (1889, No. 118).

Habitat in insula australi Novae Zeelandiae inter saxa ad ostia rivulorum aquae dulcis [etc.].—F.

Tripterygion tripinne.

Blennius tripennis (F.) *Bloch and Schneider* Syst. Ich, p. 174, 1801.
Blennius tripennis *Forster* Desc. Animal. cur. Lichtenstein, p. 125, 1844.
Tripterygium Forsteri (*Cuv. et Val.*) *Hutton* Fishes New Zealand, p. 31, 1872.

Habitat in insula australe Novae Zeelandiae [etc.].—F.

Tripterygion varium.

Blennius varius *Bloch and Schneider* Syst. Ich., p. 178, 1801; *Forster* Desc. Animal. cur. Lichtenstein, p. 127, 1844.
Tripterygion varium *Cuv. et Val.* Hist. Nat. Poiss., Vol. XI, p. 415; *Hutton* Fishes New Zealand, p. 33 1872.

Habitat ad littora saxosa insulae australis Novae Zeelandiae.—F.

ACANTHOCLINIDÆ.

Acanthoclinus litoreus.

Blennius quadridactylus (=Blennius littoreus) *Bloch and Schneider* Syst. Ich., p. 177, 1801.
Blennius littoreus *Forster* Desc. Animal. cur. Lichtenstein, p. 127, 1844.
Clinus littoreus *Cuv. et Val.* Hist. Nat. Poiss., Vol. XI, p. 389.
Acanthoclinus littoreus *Hutton* Fishes New Zealand, p. 34, 1872 (1889, No. 119).

Habitat ad littora propeostia rivulorum aquae dulcis in australi insula Novae Zeelandiae.—F.

GADIDÆ.

Pseudophycis bacchus.

Enchelyopus bachus (= G. B. F.), *Bloch and Schneider* Syst. Ich., p. 53, 1801.
Gadus bacchus, *Forster* Desc. Animal. cur. Lichtenstein, p. 120, 1844.
Lota (=Gadus bacchus) *Cur.* Regne An. (2d ed.), Vol. II, p. 334, 1829.
Lotella bacchus *Hutton* Fishes New Zealand, p. 46, 1872.
Pseudophycis bachus *Hutton* Trans. N. Z. Inst., Vol. XXII, p. 282 (List, 1889, No. 150).

Habitat in mari alluente insulam australem Novae Zeelandiae, etc.—F.

Lotella rhacina.

Phycis tinea var. (=Gadus rhacinus F), *Bloch and Schneider* Syst. Ich., p. 56, 1801.
Gadus rhacinus *Forster* Desc. Animal. cur. Lichtenstein, p. 304, 1844.
Lotella rhacinus *Hutton* Fishes New Zealand, p. 46, 1872 (List, 1889, No. 152).

Habitat in Aestuario Reginae Charlottae in Nova Zeelandia.—F.

OPHIDIIDÆ.

Genypterus blacodes.

Ophidium blacodes *Bloch and Schneider* Syst. Ich., p. 484, 1801; *Forster* Desc. Animal. cur. Lichtenstein, p. 115, 1844.
Ophidium blacodes *Cuv.* Regne An., Vol. II, p. 359, 1829.
Genypterus blacodes *Hutton* Fishes New Zealand, p. 48, 1872.

Habitat in mari quod alluit insulam australem Novae Zeelandiae, etc.—F.

PLEURONECTIDÆ.

Caulopsetta scapha.

Pleuronectes scapha (F.) *Bloch and Schneider* Syst. Ich. cur. Lichtenstein, p. 163, 1801; *Forster* Desc. Animal. cur. Lichtenstein, p. 130, 1844.
Rhombus ? scapha *Rich* Rep. Br. A. A. S., 1842, p. 27, 1843.
Pseudorhombus scaphus *Hutton* Fishes New Zealand, p. 57, 1872.

Habitat in mari alluente insulam australem Novae Zeelandiae.—F.

GOBIESOCIDÆ.

Trachelochismus pinnulatus.

Lepadogaster pinnulatus (=Cyclopterus pinnulatus F.) *Bloch and Schneider* Syst. Ich. cur. Lichtenstein, p. 2, 1801.
Cyclopterus pinnulatus *Forster* Desc. Animal. cur. Lichtenstein, p. 301, 1844.
Lepadogaster pinnulatus *Rich.* An. Rep. Br. A. A. S., 1842, p. 27, 1843.
Trachelochismus pinnulatus *Hutton* Fishes New Zealand, p. 40, 1872.

Habitat in Aestuario Reginae Charlottae in Nova Zeelandia, etc.—F.

Trachelochismus litoreus.

Cyclopterus littoreus (F.) *Bloch and Schneider* Syst. Ich., p. 199, 1801, *Forster* Desc. Animal, cur. Litchtenstein, p. 114, 1844.
Gobiesox (littoreus) *Cuv.* Regne An. (2 ed.), v. ii, p. 315, 1829.

Habitat in insula australi Novae Zeelandiae.—F.

BALISTIDÆ.

Monacanthus scaber.

Balistes scaber (F.) *Bloch and Schneider* Syst. Ich., p. 478, 1801. *Forster* Desc. Animal. cur. Lichtenstein, p. 152, 1844.
Monacanthus scaber *Rich.* Rep. Br. A. A. S. 1842, p. 29, 1843.
Monacanthus convexirostris *Hutton* Fishes, New Zealand, p. 71, 1872.

Habitat in mari alluente Novam Zeelandiam in Aestuario Reginae Charlottae (etc.).—F.

IV.

RICHARDSON'S CATALOGUES OF NEW ZEALAND FISHES.

Dr. (afterwards Sir John) Richardson contributed two slightly different lists of the fishes of New Zealand, as already indicated (see p. —). Many species are duplicated, old notices by Solander being admitted. The identification of some of these is impossible to one not having access to the original supposed to be still in the British Museum. As a correlation of the two will be interesting to some, they are here given in parallel columns, the left-hand column giving the pages and numbers of the report published by the British Association for the Advancement of Science, and the right those of the enumeration in Dieffenbach's works.

PERCOIDEÆ.

Serranus lepidopterus	15, 1	206, 1	Psendanthias lepidopterus.
Polyprion cernuum	2	2	Polyprion prognathus.
Centropristes trutta	3	3	Arripis trutta.
Centropristes nulloides	16, 4	1	Arripis trutta.
Centropristes sapidissimus	5	5	Arripis trutta.
Aplodactylus meandratus	6	207, 6	Haplodactylus meandratus.
Percis colias	7	7	Parapercis colias.
Percis niethenera	8	8	Parapercis colias.
Uranoscopus maculatus	17, 9	9	Genyagnus maculatus.
Upeneus vlamingii	10	10	Upeneoides vlamingii.
Upeneus porosus	11	11	Upeneichthys porosus.

COTTOIDEÆ.

Trigla papilionacea	18, 12	12	Trigla kumu.
Scorpæna cardinalis	13	208, 13	Scorpæna cardinalis.
Scorpæna cottoides	14	14	Scorpæna cottoides.
Scorpæna plebeia	15	15	
Scorpæna cruenta	16	16	Scorpæna cottoides.
Sebastes percoides	17	17	Sebastapistes percoides.

SCIÆNOIDEÆ.

Cheilodactylus carponemus	18	18	Cheilodactylus carpouemus.
Cheilodactylus macropterus	19, 19	19	Cheilodactylus macropterus.
Latris ? salmonea	20	209, 20	Latris lineata?
Latris lineata	27	21	Latris lineata.
Latris ciliaris	22	22	Latris ciliaris.

SPAROIDEÆ.

Pagrus guttulatus	20, 23	23	Pagrosomus auratus.
Pagrus micropterus	24	24	Pagrosomus auratus.
Pagrus latus	25	25	Pagrosomus auratus.

SCOMBEROIDEÆ.

Scomber (scombrus) solandris	26	26*	Scomber australasicus.
Thyrsites atun	27	27†	Thyrsites atun.
Gempylus solandris	28	210, 28‡	Promethichthys prometheus.
Chorinemus forsteri	21, 29	31§	Scombroides lysan.
Trachurus Novæ Zelandiæ	30	32	Trachurus trachurus.
Trachurus ? clupeoides	31	33	Trachurus trachurus.
Caranx lutescens	32	34	Caranx georgianus.
Caranx sinus-obscuri	33	35	Trachurus trachurus.
Caranx platinoides	34	36	
Caranx georgianus	35	0‖	Caranx georgianus.

SIGANOIDEÆ.

Acanthurus triostegus	22, 36	211, 39	Teuthis triostegus.

MUGILOIDEÆ.

Mugil forsteri	37	40	Agonostomus forsteri.

GOBIOIDEÆ.

Clinus littoreus	38	41	Acanthoclinus litoreus.
Acanthoclinus fuscus	39	42	Acanthoclinus litoreus.
Cristiceps australis	40	43	Cristiceps australis.
Tripterygion nigripinne ¶	23, 41	44	Tripterygion varium.
Tripterygion varium	42	45	Tripterygion varium.
Tripterygion forsteri	43	212, 46	Tripterygion tripinne.
Tripterygion fenestratum	44	47	Notoclinus fenestratus.
Tripterygion capito	45	48	Tripterygion varium.
Electris gobioides	46	49	Gobiomorphus gobioides.
Electris radiata	47	50	Electris radiata.
Electris basalis	48	50 **	Gobiomorphus gobioides.
Hemerocœtes acanthorhynchus	49	51 ††	Hemerocœtes acanthorhynchus.

* Scomber loo.
‡ Gempylus solandri.
"30. Nauerates ——?"
"38. Capros australis" (p. 211).
**50 duplicated and second numbered "50*."

† Thyrsites atun, var. altivelis.
§ "29. Histiophorus ——?"
‖ "37. Seriola cultrata" (p. 210).
¶ *T. nigripenne* in R. B. A. A. S., p. 23.
†† A long description of *H. a.* is given (pp. 212–218).

LABROIDEÆ.

Julis ? rubiginosus	51	53	Pseudolabrus celidotus.
Labrus poecilopleura	24, 50	218, 52	Pseudolabrus celidotus ?
Julis notatus	52	54	Pseudolabrus celidotus.
Julis miles	53	55	Pseudolabrus miles.
Julis celidotus	54	56	Pseudolabrus celidotus.
Odax pullus	25, 55	58*	Coridodax pullus.
Odax ? vittatus	56	59†	Odax vittatus.

CYPRINOIDEÆ.

Leuciscus ? lavaretoides	57	60‡	Gonorhynchus Greyi.

ESOCIDÆ.

Galaxias alepidotus	58	219, 61	Galaxias alepidotus.
Galaxias fasciatus	59	221, 63§	Galaxias fasciatus.
Mesites attenuatus	26, 60	0‖	Galaxias attenuatus.
Saïris scombroides	61	221, 64	Scombresox forsteri.
Hemiramphus marginatus	62	219, 62	Hemirhamphus intermedius.
Exocœtus ? subpellucens	63	221, 65¶	Exocœtus micropterus ?

CLUPEOIDEÆ.

Clupea lata	64	221, 68	Clupea sagax ?

GADOIDEÆ.

Lota baccha	65**	221, 69	Pseudophycis bachus.
Lota rhacina	27, 70	222, 70	Lotella rhacina.
Brosmius venustus	71	71	

PLATESSOIDEÆ.

Rhombus ? scapha	72	72††	Caulopsetta scapha.
Rhombus plebeius	73	73	Rhombosolea plebeia

DISCOBOLI.

Lepadogaster pinnulatus	74	225, 74	Trachelochismus pinnulatus.
Gobiesox littoreus	28, 75	75	Trachelochismus littoreus.

ANGUILLIFORMES.

Anguilla australis	76	0‡‡	Anguilla australis.
Anguilla dieffenbachii	77	77	Anguilla australis.
Ophidium blacodes	78	226, 78	Genypterus blacodes.

LOPHOBRANCHII.

Hippocampus abdominalis	79	79	Hippocampus abdominalis.

PLECTOGNATHI.

Tetraodon hamiltoni	80	80§§	Amblyrhynchotus richei.
Monacanthus scaber	29, 81	81	Monacanthus scaber.

CHIMERIDÆ.

Callorhynchus antarcticus	82	82	Callorhynchus antarcticus.

SCYLLIA.

Scyllium ? lima	83	83	Cephaloscyllium laticeps, pt. ?

CARCHARIÆ.

Carcharias (Prionodon) melanopterus	84	227, 84‖‖	Carcharinus brachyurus, pt. ?

* "57. Julis ? prasiophthalmus."
† "59. Odax vittatus."
‡ "60. Leuciscus (Ptycholepis) salmoneus."
§ Misplaced.
‖ Omitted and not at all referred to.
¶ "66, 67. Exocœtus exiliens et volitans.—Auct."
** There are no numbers between 65 and 70.
†† "72. Platessa ? (Rhombus ?) scapha."
‡‡ Anguilla australis not referred to.
"76. Echeneis naucrates, L." under "fam. Echeneideæ."
§§ "80. Tetraodon hamiltoni, sp. nov.," not described. ‖‖ "85. Carcharias (Prionodon) maoo."

	SPINACES.		
Acanthias ? maculatus	85	86*	Squalus acanthias?
	SQUATINORAIÆ.		
Rhinobates (Syrrhina) banksii	86	87	Rhinobatus banksii.
Trygonorhina fasciata	87	88	Trygonorhina fasciata
	RAIÆ.		
Raia nasuta	88	89	Raia nasuta.
	TRYGONES.†		
Trygonoptera testacea	30, 89	0‡	Dasybatis brevicaudatus.
	MYLIOBATIDES.		
Myliobatis nieuhofii	90	91	Aetobatus tenuicaudatus.
	CYCLOSTOMI.		
Heptatrema dombeyi	91	228, 92	Heptatrema cirrata.

* "86. Acanthias maculatus" without "?".

† Family name omitted in report.

‡ "90. Tæniura lymma" inserted under "fam. TRYGONES."

So far as some of the foregoing species are attributed to New Zealand by Richardson, they were so done through misidentifications, and the species really represented in the island are indicated in the second column.

NEW ZEALAND FAMILIES OF FISHES COMPARED WITH BRITISH.

The fishes of New Zealand may now be grouped into families and compared with those of the British islands. A comparative list of the families of the two regions is given in which those of New Zealand are numbered and those not represented in the colonial waters but occurring in the British waters are intercalated without numbers. In one column are given the numbers of species and genera of Britain and in another those of New Zealand. The list will also serve as a table of contents to the following catalogue:

Class, order, suborder, and family.	British.		New Zealand.		Class, order, suborder, and family.	British.		New Zealand.	
	Species.	Genera.	Species.	Genera.		Species.	Genera.	Species.	Genera.
CLASS OF LEPTOCARDIANS.					CLASS OF SELACHIANS—continued.				
Order Amphioxi.					*Order Tectospondyli*—Continued.				
1. Branchiostomidæ (Cirrostomi D.)	1	1	1	1	8. Oxynotidæ	1	1	1	1
CLASS OF MYZONTS.					(Suborder Rhinæ.)				
Order Hyperotreta.					Squatinidæ (Rhindæ D.)	1	1	0	0
					Order Asterospondyli.				
2. Heptatremidæ			1	1	9. Scylliorhinidæ (Scylliidæ D.)	3	3	1	0
Myxinidæ	1	1			10. Isuridæ (Lamnidæ D.)	1	1	2	2
Order Hyperoartii.					11. Cetorhinidæ	1	1	0	0
					12. Alopiidæ	1	1	1	1
3. Petromyzontidæ	3	2	2	1	13. Galeidæ (Carchariidæ D.)	3	3	3	3
CLASS OF SELACHIANS.					14. Sphyrnidæ	1	1	1	1
Order Opistharthri.					*Order Platysomi.*				
4. Hexanchidæ (Notidanidæ D.)	1	1	1	1	(Suborder Pachyura.)				
Order Tectospondyli.					15. Rhinobatidæ	0	0	2	2
					16. Raiidæ	10	4	1	1
(Suborder Squali.)					17. Torpedinidæ	2	1	2	1
					(Suborder Masticura.)				
5. Echinorhinidæ	1	1	1	1	18. Dasybatidæ or Trygonidæ (D.)	1	1	3	1
6. Dalatidæ or Scymnidæ	1	1	1	1	Cephalopteridæ	1	1	0	0
7. Squalidæ or Spinacidæ (D.)	1	1	1	1	19. Aetobatidæ	1	1	1	1

Class, order, suborder, and family.	British.		New Zealand.	
	Species.	Genera.	Species.	Genera.
CLASS OF SELACHIANS—continued.				
Order Holocephali.				
20. Chimæridæ	1	1	2	1
CLASS OF TELEOSTOMES OR FISHES.				
Order Chondrostei.				
Acipenseridæ	1	1	0	....
Order Malacopterygii.				
21. Haplochitonidæ	0	....	1	1
22. Galaxiidæ	0	....	6	2
23. Gonorhynchidæ	0	....	1	1
24. Chanеidæ	0	....	1	1
25. Clupeidæ	5	3	2	1
26. Stolephoridæ (Engraulididæ)	1	1	1	1
27. Argentinidæ	2	2	2	2
Thymallidæ	1	1	....	....
Salmonidæ	7	3	0	0
Order Iniomi.				
28. Synodontidæ	0	0	1	1
29. Aulopidæ	0	0	1	1
30. Gonostomidæ	0	0	1	1
31. Maurolicidæ	1	1	2	2
Paralepididæ (Scopelidæ)	1	1	....	....
32. Myctophidæ (Scopelidæ)	0	0	4	1
33. Sternoptychidæ	1	1	1	1
Order Plectospondyli.				
Cyprinidæ	14	5	0	0
Cobitidæ	2	2	0	0
Order Apodes.				
(Suborder Enchelycephali.)				
34. Leptocephalidæ (Congridæ)	1	1	4	2
35. Anguillidæ	1	1	3	1
36. Ophichthyidæ	0	0	1	1
(Suborder Colocephali.)				
37. Muræniдæ	1	1	1	1
Order Heteromi.				
38. Notacanthidæ	1	1	1	1
Order Teleocephali.				
(Suborder Haplomi.)				
Esocidæ (D.)	1	1	....	....
(Suborder Synentognathi.)				
39. Exocœtidæ (Scombresocidæ D.)	3	3	3	2
Belonidæ	1	1	0	0
(Suborder Percesoces.)				
40. Sphyræniдæ (D.)	1	1	1	1
41. Atherinidæ (D.)	2	1	1	1
42. Mugilidæ (D.)	2	1	2	2
(Suborder Acanthopterygii.)				
43. Berycidæ	0	0	1	1
44. Trachichthyidæ	0	0	3	1

Class, order, suborder, and family.	British.		New Zealand.	
	Species.	Genera.	Species.	Genera.
CLASS OF TELEOSTOMES OR FISHES—continued.				
Order Teleocephali—Continued.				
(Suborder Acanthopterygii)—Cont'd.				
45. Carangidæ	3	3	9	7
46. Bramidæ	1	1	1	1
47. Diretmidæ	0	0	1	1
48. Stromateidæ	4	3	1	1
49. Nomeidæ	0	2	1	1
50. Scombridæ	7	5	3	3
51. Gempylidæ	0	0	1	1
52. Lepidopodidæ	1	1	2	2
Trichiuridæ	1	1	0	0
53. Histiophoridæ	0	0	1	1
54. Xiphiidæ	1	1	1	1
55. Lampridiдæ (Coryphænidæ gen. Day)	1	1	1	1
56. Zeidæ (Cyttidæ D.)	1	1	5	5
57. Caproidæ (Carangidæ gen. Day)	1	1	....	....
Luvaridæ (Coryphænidæ gen. Day)	1	1	....	....
58. Tenthididæ	0	0	1	1
Trachinidæ	2	2	0	0
59. Serranidæ	1	4	4	3
Percidæ	2	2	0	0
60. Lutjanidæ	0	0	1	1
61. Arripididæ	0	0	1	1
62. Pentacerotidæ	0	0	1	1
63. Cyphosidæ	0	0	4	3
Sciænidæ	1	1	0	0
64. Sparidæ	10	5	1	1
65. Mullidæ	1	1	2	1
66. Pomacentridæ	0	0	1?	1?
67. Labridæ	7	6	1	1
68. Odacidæ	....	....	2	2
69. Haplodactylidæ	....	....	12	4
70. Scorpænidæ	1	1	4	3
71. Cottidæ	4	3	1	1
Agonidæ	1	1	0	0
Liparididæ	2	1	....	....
Cyclopteridæ (Discoboli D.)	1	1	....	....
72. Congiopodidæ	0	0	1	1
73. Percophidæ	0	0	2	2
74. Notothenidæ	0	0	5	1
75. Bovichthyidæ	0	0	1	1
76. Uranoscopidæ	0	0	5	2
77. Leptoscopidæ	0	0	4	2
78. Hemerocœtidæ	0	0	1	1
79. Gobiidæ (D.)	9	3	3	2
Callionymidæ	2	1	....	....
Cepolidæ	1	1	....	....
Blenniidæ	4	2	....	....
80. Clinidæ	0	0	8	5
Anarrhichadidæ	1	1	0	0
Stichæidæ	2	2	0	0
Xiphidiontidæ	1	1	0	0
81. Acanthoclinidæ	0	0	1	1
82. Gadopsidæ	0	0	1	1
83. Lycodidæ	1	1	1	1
84. Brotulidæ	0	0	1	1
85. Ophiidæ (D.)	1	1	1	1
Fierasferidæ	1	1	....	....
Ammodytidæ	3	2	....	....
(Suborder Craniomi.)				
86. Triglidæ	7	2	3	2
(Suborder Tæniosomi.)				
87. Trachypteridæ	1	1	2	1
88. Regalecidæ	1	1	2	1

Class, order, suborder, and family.	British.		New Zealand.	
	Species.	Genera.	Species.	Genera.
CLASS OF TELEOSTOMES OR FISHES—continued.				
Order Teleocephali—Continued.				
(Suborder Xenopterygii.)				
89. Gobiesocidæ	----	----	4	3
(Suborder Discocephali.)				
90. Echeneididæ (Scombridæ g. D.)	1	1	1	1
(Suborder Anacanthini.)				
Ranicipitidæ	1	1	----	----
91. Gadidæ	16	11	5	4
92. Merlucciidæ	1	1	1	1
93. Bregmacerotidæ	0	0	1	1
94. Macruridæ	1	1	4	4
(Suborder Heterosomata.)				
95. Pleuronectidæ	14	11	11	6
Soleidæ	4	3	0	0
Order Hemibranchii.				
Gasterosteidæ	3	3	0	0
Fistulariidæ	0	0	‡	‡
96. Macrorhamphosidæ	1	1	1	1
CLASS OF TELEOSTOMES OR FISHES—continued.				
Order Lophobranchii.				
97. Syngnathidæ	5	4	5	4
98. Hippocampidæ	1	1	2	2
Order Plectognathi.				
(Suborder Sclerodermi.)				
99. Balistidæ *	2	1	1	1
(Suborder Ostracodermi.)				
100. Ostraciontidæ	0	0	2	2
(Suborder Gymnodontes.)				
101. Tetraodontidæ †	1	1	1	1
102. Diodontidæ †	0	0	1	1
103. Molidæ †	2	2	1	1
Order Pediculati.				
104. Antennariidæ	0	0	1	1
105. Ceratiidæ	0	0	1	1
Lophiidæ	1	1	0	0

* Sclerodermi D. † Gymnodontes D. ‡ Recorded in F. N. Z. (p. 39), but omitted in list.

VI.

DEDUCTIONS FROM COMPARATIVE TABLE.

An analysis of the results recorded and tabulated in this article shows that the following twenty-five families are represented in the New Zealand seas and not in the British, viz:

Heptatremidæ.
Rhinobatidæ.
Gonorhynchidæ.
Chaneidæ.
Myctophidæ.
Ophichthyidæ.
Beryeidæ.
Trachichthyidæ
Nomeidæ.
Haplodactylidæ.
Arripididæ.
Lutjanidæ.
Kyphosidæ.
Odacidæ.
Congiopodidæ.
Uranoscopidæ.
Leptoscopidæ.
Bovichthyidæ.
Percophidæ.
Nototheniidæ.
Clinidæ.
Acanthoclinidæ.
Hemerocœtidæ.
Brotulidæ.
Bregmacerotidæ.

Of these eleven are peculiar to the southern hemisphere, viz:

Gonorhynchidæ.
Trachichthyidæ.
Arripididæ.
Odacidæ.
Congiopodidæ.
Leptoscopidæ.
Bovichthyidæ.
Percophidæ.
Nototheniidæ.
Acanthoclinidæ.
Hemerocœtidæ.

Again, four are also represented in the Northern Pacific, but not in the Northern Atlantic, viz:

Heptatremidæ.
Chaneidæ.
Haplodactylidæ.
Bregmacerotidæ.

The remaining ten, although without representatives in the British seas, have quite a general distribution, viz:

Rhinobatidæ.	Lutjanidæ.
Myctophidæ.	Kyphosidæ.
Ophichthyidæ.	Uranoscopidæ.
Berycidæ.	Clinidæ.
Nomeidæ.	Brotulidæ.

A comparison of the fresh water representatives of the two faunas shows even a more striking contrast. Those characteristic of the Northern Hemisphere are, with the exception of the *Argentinidæ*, entirely unrepresented in the Southern, while the Antipodal types are wanting in the Northern zones. The fresh water fishes of New Zealand belong to three families, viz:

Haplochitonidæ.	Argentinidæ.
Galaxidæ.	(Retropinna.)

Of course the Anguillids, which are marine fishes of general distribution, breeding only in the sea, and the species introduced from Britain, are not considered in this connection.

As to some remaining features and peculiarities, the list and tabulated summary will be self-explanatory; as to others, a comparison with the faunas of the corresponding isotherms of Australia and the Southern Hemisphere generally is necessary.

A few more remarks, however, seem to be called for.

The fishes enumerated by Prof. Hutton in his recent "List of the New Zealand Fishes," and therefore carried over into the following enumeration, belong to no less than six distinct geographical realms, viz:

1. Notalian realm, including most of the species.

2. Antarctalian realm, characterized especially by the Nototheniids.

3. Pelagalian realm, represented by the isuroid and some other sharks, large Scombrids, Gempylids, a Nomeid, several Carangids (*Naucrates*, *Seriola*, *Caranx*), the Lampridid, Scopelids, and various others.

4. Bassalian realm, to which belong the *Bathysaurus*, *Benthodesmus*, *Halargyreus*, *Bathygadus*, most Macrurids, *Egeoniehthys*, and several other less typical forms.

5. Tropicalian realm, from which have wandered the *Ophisurus*, *Muræna*, *Sphyræna*, and (if they have really been found in New Zealand) the *Teuthis*, *Dascyllus*, and *Ostracion*, besides others.

6. Ornithogæan realm, almost indistinguishable, so far as the fishes are concerned, from the Austrogæan and Amphigæan realms. This includes all the fresh-water fishes which mainly represent two families, Haplochitonids and Galaxiids, and whose principal genus, *Galaxias*, is exemplified by nearly related species in the colder waters of Australia and South America.

The consideration of these various elements and comparison of them with those of other regions point to the following conclusions:

The main marine fauna of New Zealand is derived from representatives of the general stock which has become developed in the great notalian realm. The number of species apparently peculiar to the province and therefore modified from other or earlier representatives indicates a long period of isolation in accordance with its distance from the nearest continents and the depth of the intervening ocean. The percentage of such peculiar species seems to entitle it to rank as a distinct region (or subregion) rather than as an integral portion of the notalian region composed of the isothermal portions of Australia and Tasmania, as has been generally done. A more extended study and actual comparison of the species of the two regions may, however, compel a reconsideration of this view.

The fresh-water fishes must have been derived from the same common source as those of the isothermal portions of Australia (of course including Tasmania) and South America. There may not have been a continuity of land at any one time between South American, Australia, and New Zealand, but, at some remote period in the past, it is at least possible that there was a region in which the Galaxiids and Haplochitonids were developed, and subsequently representatives of those families might have found their way into the regions where they now abound. But, it may be urged, such a derivation is only possible and there may have been other means for diffusion of the same types.

The alternative then lies between two possibilities:

1. According to some, the forms of fresh-water fishes common to the now widely isolated lands may have been transported afar and distributed in some unnatural manner. (*a*) The progenitors of the existing species may have been, for example, entombed in masses of ice, and such may have been carried into the ocean and wafted to distant regions, where they may have found congenial waters, been liberated from their long imprisonment, mated, and propagated their race. (*b*) They may have even survived a long sojourn in salt water into which they wandered. (*c*) They may have originated from congeneric species formerly existing in the ocean, but now extinct therein and restricted to fresh water.

2. According to others, community in type must be the expression of community of origin, and the presence of fishes of long-established fresh-water types must imply continuity or at least contiguity of the lands in the midst of which they occur at some one time or other.

Some physical geographers and thalassographers have found difficulty in admitting the existence of land where now deep oceans exist, and have consequently denied the probability of land connection between the southern lands. The objections do not appear to me to be insuperable. It is well known that the highest mountain chains are of comparatively recent geological age. It remains then to consider which is the more probable, (1) that the types now common to distant regions were distributed in some unnatural manner by means referred to, or (2) that they are the descendants of forms once wide ranging over lands now submerged.

The distribution of different types of fresh-water fishes is analogous to the geographical range of amphibians, mollusks, crustaceans, and other animals, and recent paleontological finds indicate that even the Thylacinids (or at least forms resembling them) were formerly natives of southern America. While it may be admitted that it is possible that *one* or *two* types may have been distributed in some such unnatural manner as has been suggested, it is highly improbable that *all* the forms common to the distant regions could have been so distributed.

The time at which immigration took place into the regions now occupied by the Galaxiids and Haplochitonids can not be ascertained in the present stage of ignorance of the paleontological history of those forms. We can only conjecture from a knowledge of the paleontological history of others.

The various classes of animals differ remarkably in persistence of type or rapidity of change.

On the one hand, echinoderms, mollusks, and articulates are very persistent in essential structural features. Of mollusks, for example, Unionids, Lymnæids, Valvatids, Melaniids, and Viviparids were not only represented by undoubted members of the same families in Mesozoic times, but even *genera* had come into existence which are still extant and were manifest in species little divergent from some which live in streams which course lands in latitudes and longitudes where they once flourished.

On the other hand, mammals have undergone such changes that scarcely a single *family* which existed in Eocene times has survived to the present, or, in other words, few, if any,* existing families can be traced back to the Eocene into forms which are now recognized as members of the same family.

It thus appears that in the same land, in early Tertiary times, mammals entirely unlike those now living, and belonging to different families, walked the earth through which coursed streams in which flourished mollusks quite similar to those now living in succeeding courses, and the same mammals might have crushed under foot gastropods, also almost undistinguishable from some still existing.†

Fishes to a certain extent are intermediate between invertebrates and mammals in persistence of type, and consequently as indicators of geological periods. Few teleostomous families can be traced farther back than Cretaceous times, and very few, if any, genera.

In the present stage of science, then, we may be permitted to postulate (fishes being congeneric in New Zealand, Australia, and South America), that there existed some terrestrial passage way between the several regions at a time as late as the close of the Mesozoic period. The evidence

*After a careful survey of all the families of mammals, I can not recognize a single one which now flourishes which had undoubted representatives in the Eocene period, or at least of which unequivocal remains have been found.

†As is well known land shells like those of the present epoch lived as early as the Carboniferous.

of such a connection afforded by congeneric fishes is fortified by analogous representatives among insects, mollusks, and even amphibians. The separation of the several areas must, however, have occurred little later than the early Tertiary, inasmuch as the salt water fishes of corresponding isotherms found along the coasts of the now widely separated lands are to such a large extent specifically different. In general, change seems to take place more rapidly among marine animals than fresh-water representatives of the same class.

VII.

NOMENCLATURE.

In deciding on the nomenclature adopted, obedience has always been paid to the precepts inculcated by the British and American associations for the advancement of science, and lately reënforced by the French association and the American Ornithologists' Union. The lawlessness that has long prevailed in this respect and the obtrusion of whims for laws have retarded the progress toward a settled nomenclature, although the extent to which rules of nomenclature have been violated has been hidden by a tacit consensus of those unwilling or unable to think for themselves.

A considerable proportion of the species are involved in more or less doubt as to their correct nomenclature, it being questionable whether some are identical with the forms with which they have been identified, and whether others are distinct from previously known ones. The exact generic relations of a few remain also to be determined. It is partly in order to have a basis from which to start anew for investigation that the present list is prepared.

All the species enumerated in Prof. Hutton's "List of the New Zealand Fishes" are repeated in the present catalogue; but nine of these species have very little claim to a place therein, and should probably be eliminated. They are the following:

19 (14) Rhinobatus banksii.
20 (15) Trygonorhina fasciata.
55 (203) Anguilla latirostris.
99 (61) Tenthis triostegus.
112 (135) Dascyllus aruanus.
131 (46) Chilodactylus carponemus.
140 (50) Cottapistus cottoides.
174 (157) Gadopsis marmoratus.
224 (217) Ostracion fornasini.

All of these, excepting *Anguilla* and *Gadopsis*, were marked by Prof. Hutton himself as doubtful members of the New Zealand fauna. But the most doubtful of all appear to me to be the Anguillid and Gadopsid.

Anguilla latirostris has been attributed to New Zealand because a specimen, described by Dr. Gray as "*Anguilla dieffenbachii*," and supposed to have been taken in New Zealand, was identified with that species by Dr. Günther (Cat., IV, 33). Dr. Gray, under the name *Anguilla dieffenbachii*, adds: "Inhabits the River Thames, New Zealand.—Dr. Dieffenbach." Inasmuch as no other specimen has been recorded from that locality, we may be permitted, till another specimen has been found, to believe that there may have been some confusion or transposition of labels.*

Gadopsis marmoratus is recorded by Prof. Hutton as a New Zealand fish, and reference is made to Richardson ("Ann. Mag. Nat. Hist., ser. 4, vol. I, p. 342"). No mention is made of the fish on the page referred to, and Sir John Richardson had died (June 5, 1865) before the volume cited was published (1868). Some confusion of notes must have happened to the distinguished New Zealand professor; but, whether Richardson has elsewhere recorded the species as an inhabitant of New Zealand or not, it is extremely improbable that such a conspicuous fresh-water fish should have been overlooked by other observers.

Of the two numbers prefixed to almost every species, the former, of course, indicates the sequence of the species adopted in the enumeration, and the latter (inclosed within parentheses) the number attached to it in Prof. Hutton's list.

* "Mr. Henry Travers brought three specimens of this eel from the Chatham Islands." Hutton T. N. Z. I., Vol. V, p. 271.

Class of LEPTOCARDIANS.

1. BRACHIOSTOMIDÆ.

1 (224) Branchiostoma (near bassanum?).
Branchiostoma lanceolatum (*Pall.*) *Hutton*, Fishes N. Z., p. 88.

Class of MYZONTS.

Order HYPEROTRETI.

2. HEPTATREMIDÆ.

2 (223) Heptatrema cirrata.
Bdellostoma cirrhatum (*Forst.*) *Hutton*, Fishes N. Z., p. 87.

Order HYPEROARTII.

3. PETROMYZONTIDÆ.

3 (222) Geotria australis.
Geotria australis (*Gray*) *Hutton*, Trans. N. Z. Inst., vol. v, p. 272. pl. 12 f. [4] 1873.
4 (221) Geotria chilensis.
Geotria chilensis (*Gray*) *Hutton*, Fishes N. Z., p. 87; *Hutton*, Trans. N. Z. Inst., vol. v, p. 271; vol. viii, p. 216, 1875.

Class of SELACHIANS.*

Order OPISTHARTHRI.

4. HEXANCHIDÆ.

5 (8) Notorhynchus indicus.
Notidanus indicus (*Cuv.*) *Hutton*, Fishes N. Z., p. 79; Trans. N. Z. Inst., vol. v, p. 271, 1873.

Order CYCLOSPONDYLI.

5. ECHINORHINIDÆ.

6 (13) Echinorhinus spinosus.
Echinorhinus spinosus (*Gmel.*) *Parker*, Trans. N. Z. Inst., vol. xvi, p. 280, 1884.

6. DALATIIDÆ.

7 (12) Dalatias lichia.
Scymus lichia (*Cuv.*) *Parker*, Trans. N. Z. Inst., vol. xv, p. 222.

7. SQUALIDÆ.

8 (11) Squalus acanthias.
Acanthias vulgaris (*Risso*) *Hutton*, Fishes N. Z., p. 76.

8. OXYNOTIDÆ.

9 (10) Oxynotus centrina.
Centrina salviana (*Risso*) *Hutton*, Trans. N. Z. Inst., vol. xxii, p. 276.

Order ASTEROSPONDYLI.

9. SCYLLIORHINIDÆ.

10 (9) Cephaloscyllium laticeps.
Scyllium laticeps (*Duméril*) *Hutton*, Fishes N. Z., p. 79; *Hutton*, Trans. N. Z. Inst., vol. viii, p. 216.

10. ISURIDÆ.

11 (6) Carcharodon carcharias.
Carcharodon rondeletii (*Müll.* and *Henle*) *Hutton*, Fishes N. Z., p. 78.

* The following type was subsequently eliminated: Heterodontus Philippii Cestracion Philippii (*Lac.*) *Hutton*, Fishes N. Z., p. 80.

12 (5) Isurus cornubicus.
Lamna glauca (*M.* and *H.*) *Hutton*, Fishes N. Z., p. 77.
Lamna cornubica (*Gmel.*) *Haast*, Trans. N. Z. Inst., vol. VII, p. 237.

11. CETORHINIDÆ.

13 (—) Cetorhinus maximus.
Selache maxima *Cheeseman*, Trans. N. Z. I., vol. XXIII, p. 126.

12. ALOPIIDÆ.

14 (7) Alopias vulpes.
Alopecias vulpes (*Gmel.*) *Hutton*, Fishes N. Z., p. 78.

13. GALEIDÆ.

15 (2) Galeus antarcticus.
Mustelus antarcticus (*Günth.*) *Hutton*, Fishes N. Z., p. 76, fig. 123; *Parker*, Trans. N. Z. Inst., vol. XV, p. 219, pl. 30.
16 (4) Galeorhinus australis.
Galeus canis (*L.*) *Hutton*, Fishes N. Z., p. 81.
17 (1) Carcharinus brachyurus.
Carcharias brachyurus (*Günther*) *Hutton*, Fishes N. Z., p. 75.

14. SPHYRNIDÆ.

18 (3) Sphryna zygæna.
Zygæna malleus (*Risso*) *Hutton*, Fishes N. Z., p. 76; *Hutton*, Trans. N. Z., Inst., vol. V, p. 271.

Order HYPOTREMI.

Suborder SARCURA.

15. RHINOBATIDÆ.

19 (14) Rhinobatus banksii. (d. @ hab.)
Rhinobatis banksii (*Müll.* and *Henle*) *Hutton*, Fishes N. Z., p. 82.
20 (15) Trygonorhina fasciata. (d. @ hab.)
Trygonorhina fasciata (*Müll.* and *Henle*) *Hutton*, Fishes N. Z., p. 82.

16. RAIIDÆ.

21 (18) Raia nasuta.
Raia nasuta (*Solander*) *Hutton*, Fishes N. Z., p. 84; *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 216.

17. TORPEDINIDÆ.

22 (16) Torpedo fairchildi.
Torpedo fairchildi *Hutton*, Fishes N. Z., p. 83, fig. 134.
23 (17) Torpedo fusca.
Torpedo fusca *Parker*, Trans. N. Z Inst., vol. XVI, p. 281, pl. 23.

Suborder MASTICURA.

18. DASYBATIDÆ.

24 (19) Dasybatis brevicaudatus.
Trygon thalassia (*Columna*) *Hutton*, Fishes N. Z., p. 85.
Trygon Kuhlii (*M. & H.*) *Hutton*, Fishes N. Z., p. 85.
Trygon brevicaudatus *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 216.

19. AETOBATIDÆ.

25 (20) Aetobatus tenuicaudatus.
Myliobatis aquila *Hutton*, Fishes N. Z., p. 86.
Myliobatis tenuicaudatus, *Hector*, Trans. N. Z. Inst., vol. IX, p. 286.

Order HOLOCEPHALI.

20. CHIMÆRIDÆ.

26 (21) Callorhynchus antarticus.
Callorhynchus antarticus (*Lacep.*) *Hutton*, Fishes N. Z., p. 71.
27 (22) Callorhynchus dasycaudatus.
Callorhynchus dasycaudatus *Colenso*, Trans. N. Z. Inst., vol. XI, p. 299, pl., 14.

Class of TELEOSTOMES or true Fishes.

Order MALACOPTERYGII.

21. HAPLOCHITONIDÆ.

28 (196) Prototroctes oxyrhynchus.
Prototroctes oxyrhynchus (*Günth.*) *Hutton*, Fishes N. Z., pp. 57 (*Hector*) 123, fig. 21; *Arthur*, Trans. N. Z. Inst., vol. XVII, p. 171.

22. GALAXIIDÆ.

29 (185) Galaxias alepidotus.
Galaxis alepidotus (*Forst.*) *Hutton*, Fishes N. Z., p. 58.
30 (186) Galaxias fasciatus.
Galaxias fasciatus (*Gray*) *Hutton*, Fishes N. Z., pp. 59 (*Hector*), 128, fig. 94.
31 (187) Galaxias brevipinnis.
Galaxias brevipinnis (*Günth.*) *Hutton*, Fishes N. Z., p. 59.
Galaxias grandis *Haast*, Trans. N. Z. Inst., vol. V, p. 278, vide *Hutton*, vol. VI, p. 107.
32 (188) Galaxias olidus.
Galaxias olidus (*Günth.*) *Hutton*, Trans. N. Z. Inst., vol. V, p. 270.
33 (189) Galaxias attenuatus.
Galaxias attenuatus (*Jenyns*) *Hutton*, Fishes N. Z., p. 60, fig. 96.
34 (190) Neochanna apoda.
Neochanna apoda (*Günth.*) *Hutton*, Fishes N. Z., pp. 61 (*Hector*), 130, fig. 97.

23. GONORHYNCHIDÆ.

35 (197) Gonorhynchus greyi.
Gonorhynchus greyi (*Rich.*) *Hutton*, Fishes N. Z., pp. 62 (*Hector*), 119, fig. 98.

24. CHANEIDÆ.

36 (201) Chanos salmoneus.
Chanos salmoneus (*Forst.*) *Hutton*, Fishes N. Z., p. 64, fig. 101.

25. CLUPEIDÆ.

37 (199) Clupea sagax.
Clupea sagax (*Jenyns*) *Hutton*, Fishes N. Z., p. 93, fig. 100; *Arthur*, Trans. N. Z. Inst., vol. XV, p. 208.
38 (200) Clupea antipodum.
Clupea sprattus (*Linn.*) *Hutton*, Fishes N. Z., p. 133; *Arthur*, Trans. N. Z. Inst., vol. XV, p. 203; *Hutton*, Trans. N. Z. Inst., vol. XV, p. 270, pl. 12, f.—

26. STOLEPHORIDÆ.

39 (198) Stolephorus antipodum.
Engraulis encrasicholus (*Linn.*) *Hutton*, Fishes N. Z., p. 62, fig. 99.
Engraulis encrasicholus, var. *antipodum* (*Günth.*) *Hutton*, Trans. N. Z. Inst., vol. V, p. 270.

27. ARGENTINIDÆ.

40 (195) Argentina decagon.
Argentina decagon *Clarke*, Trans. N. Z. Inst., vol. XI, p. 296, pl. 14, f.
41 (194) Retropinna richardsonii.
Retropinna richardsoni (*Gill*) *Hutton*, Fishes N. Z., pp. 58, 126, fig. 92.
Retropinna osmeroides *Hector*, Trans. N. Z. Inst., vol. III, p. 154, pl. 19, f. 1.

Order INIOMI.

28. AULOPIDÆ.

42 (180) Chlorophthalmus gracilis.
Chlorophthalmus gracilis *Günth.*, Ann. & Mag. Nat. Hist. (5), vol. XXI, p. 182.

29. SYNODONTIDÆ.

43 (179) Bathysaurus ferox.
Bathysaurus ferox *Günther*, Ann. & Mag. Nat. Hist. (5), vol. II, p. 182.

30. GONOSTOMIDÆ.

44 (191) Phosichthys argenteus.
Phosichthys argenteus *Hutton*, Fishes N. Z., p. 56.
Phosichthys argenteus *Hutton*, Trans. N. Z. Inst., vol. V, p. 269, pl. 15, f.

31. MAUROLOCIDÆ.

45 (193) Maurolicus australis.
Maurolicus australis *Hector*, Trans. N. Z. Inst., vol. VII, p. 250, pl. 11, f.
Gonostoma australis *Hutton*, Trans N. Z. Inst., vol. VIII, p. 215.
Maurolicus amethystino-punctatus (*Cocco*) *Günther*, *Ann. & Mag. Nat. Hist. 4), vol. XVII, p. 399; Trans. N. Inst., vol. IX, p. 172.

32. MYCTOPHIDÆ.

46 (175) Lampadena parvimanus.
Scopelus parvimanus (*Günth.?*) *Hutton*, Trans. N. Z. Inst., vol. V, p. 269, pl. 15, f. [5].
47 (176) Myctophum hectoris.
Scopelus hectoris *Günth.*, Ann. & Mag. Nat. Hist. (4), vol. XVII, p. 399, 1876; Trans. N. Z. Inst., vol IX, p. 171.
48 (177) Myctophum boops.*
Scopelus boops (*Rich.*) *Hutton*, Trans. N. Z. Inst., vol. V, p. 269.
49 (178) Stenobrachius coruscans.*
Scopelus coruscans (*Rich.*) *Hutton*, Trans. N. Z. Inst., vol. V, p. 270.

33. STERNOPTYCHIDÆ.

50 (192) Argyropelecus intermedius.
Argyropelecus intermedius *Clarke*, Trans. N. Z. Inst., vol. X, p. 244, pl. 6 (2 fig.)

Order APODES.

34. LEPTOCEPHALIDÆ.

51 (205) Leptocephalus conger.
Conger vulgaris (*Cuv.*) *Hutton*, Fishes N. Z., p. 66, fig. 105.
52 (206) Congermuræna habentata.
Congromuræna habentata (*Rich.*) *Hutton*, Fishes N. Z., p. 66, fig. 106.

35. ANGUILLIDÆ.

53 (202) Anguilla aucklandica.
Anguilla aucklandica (*Rich.*) *Hutton*, Fishes N. Z., pp. 64, (*Hector*) 131, fig. 102.
54 (204) Anguilla australis.
Anguilla australis (*Rich.*) *Hutton*, Fishes N. Z., p. 65, fig. 104.
55 (203) Anguilla latirostris.
Anguilla latirostris (*Risso*) *Hutton*, Fishes N. Z., p. 65; Trans. N. Z. Inst., vol. V, p. 271.

36. OPHICHTHYIDÆ.

56 (207) Ophisurus serpens.
Ophisurus serpens (*L.*) *Hutton*, Fishes N. Z., p. 66.

37. MURÆNIDÆ.

57 (208) Muræna krullii.
Mauræna krullii *Hector*, Trans. N. Z. Inst., vol. IX, p. 468, pl. 8, f. [3].

Order HETEROMI.

38. NOTACANTHIDÆ.

58 (209) Notacanthus sexspinis.
Notacanthus sexspinis (*Rich.*) *Hutton*, Fishes N. Z., p. 39.

Order TELEOCEPHALI.

Suborder SYNENTOGNATHI.

39. EXOCŒTIDÆ.†

59 (183) Exocœtus micropterus.
Exocœtus micropterus (*C. and V.*) *Hutton*, Fishes N. Z., p. 54.
60 (184) Exocœtus speculiger.
Exocœtus speculiger (*C. and V.*) *Hutton*, Fishes N. Z., p. 55.

* Sea between Australia and New Zealand (Dr. Hooker).—*Hutton.*

†Arrhamphus sclerolepis (*Günth.*) *Hutton*, Fishes N. Z., p. 54, has been wrongly credited to New Zealand and is a Queensland fish (*Hutton*, Trans. N. Z. Inst., vol. V, p. 269).

61 (182) Hemirhamphus intermedius.
Hemirhamphus intermedius (*C.* and *V.*) *Hutton*, Fishes N. Z., pp. 53, (*Hector*) 118, fig. 86.

62 (181) Scombresox forsteri.
Scombresox forsteri (*C.* and *V.*) *Hutton*, Fishes N. Z., p. 53.

Suborder PERCESOCES.

40. SPHYRÆNIDÆ.

63 (121) Sphyræna obtusata.
Sphyræna obtusata (*C.* and *V.*) *Kirk*, Trans. N. Z. Inst., vol. XII, p. 310, f.

41. ATHERINIDÆ.

64 (122) Atherina pinguis.
Atherina pinguis (*Lacep.*) *Kirk*, Trans. N. Z. Inst., vol. XII, p. 309, f.

42. MUGILIDÆ.

65 (123) Mugil cephalotus.
Mugil perusii (*C.* and *V.*?) *Hutton*, Fishes N. Z., p. 36; Trans. N. Z. Inst., vol. V, p. 264, pl. 9.

66 (124) Agonostomus forsteri.
Agonostoma forsteri (*Bl.*) *Hutton*, Fishes N. Z., pp. 37, 114, (*Hector*) fig. 58.

Suborder ACANTHOPTERYGII.

43. BERYCIDÆ.

67 (54) Beryx affinis.
Beryx affinis *Günth.*, Ann. Mag. Nat. Hist. (5), vol. XX, p. 238; *Hector*, Trans. N. Z. Inst., vol. IX, p. 466, pl. 9, f.

44. TRACHICHTHYIDÆ.

68 (51) Trachichthys elongatus.
Trachyichthys elongatus (*Günth.*) *Hutton*, Fishes N. Z., p. 12.

69 (52) Trachichthys intermedius.
Trachichthys intermedius *Hector*, Trans. N. Z. Inst., vol. VII, p. 245, pl. 11, f.

70 (53) Trachichthys trailii.
Trachichthys trailli *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 212; *Arthur*, Trans. N. Z. Inst., vol. XVII, p. 162.

45. CARANGIDÆ.

71 (63) Caranx georgianus.
Caranx georgianus (*C.* and *V.*) *Hutton*, Fishes N. Z., pp. 16, (*Hector*) 110, fig. 24.

72 (64) Caranx koheru.
Caranx koheru *Hector*, Trans. N. Z. Inst., vol. VII, p. 247, pl. 11, f.

73 (62) Trachurus trachurus.
Trachurus trachurus (*L.*) *Hutton*, Fishes N. Z., pp. 16; (*Hector*) 110, fig. 23.

74 (65) Seriola lalandii.
Seriola lalandii (*C.* and *V.*) *Hutton*, Fishes N. Z., p. 17; (*Hector*) 111, fig. 25.

75 (71) Naucrates ductor.
Naucrates ductor (*L.*) *Hutton*, Fishes N. Z., p. 18.

76 (67) Seriolella bilineata.
Neptomenus bilineatus *Hutton*, Trans. N. Z. Inst., vol. V, p. 261, pl. 8, f.

77 (68) Seriolella porosa.
Seriolella porosa (*Guichen.*) *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 211.

78 (66) Seriolella brama.
Neptonemus brama (Günth.) *Hutton*, Fishes N. Z., pp. 21; (*Hector*) 112, fig. 31.

79 (70) Evistius huttoni.
Platystethus huttoni *Günth.*, Ann. and Mag. N. Hist. (4), vol. XVII, p. 395; Trans. N. Z. Inst., vol. IX, p. 470; Report on Pelagic Fishes of *Challenger*, p. 13, pl. 2.

46. BRAMIDÆ.

80 (77) Brama squamosa.
Toxotes squamosus *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 210.
Brama squamosa (*Bl.*) *Hector*, Trans. N. Z. Inst., vol. IX, p. 465, pl. 9, f.

47. DIRETMIDÆ.

81 (79) Diretmus aureus.
Discus aureus *Campbell*, Trans. N. Z. Inst., vol. XI, p. 297, pl.

48. STROMATEIDÆ.

82 (69) Neptotichthys violaceus.
Ditrema violaceum *Hutton*, Trans. N. Z. Inst., vol. v, p. 261, pl. 8, f.
Neptotichthys violaceus, Trans. N. Z. Inst., vol. XXII, p. 278.

49. NOMEIDÆ.

83 (80) Gasteroschisma melampus.
Gasteroschisma melampus (*Rich.*) *Hutton*, Fishes N. Z., p. 20; *Hutton*, Trans. N. Z. Inst., vol. VI, p. 104, pl. 18, f.

50. SCOMBRIDÆ.

84 (81) Scomber australasicus.
Scomber australasicus (*C. and V.*) *Hutton*, Fishes N. Z., pp. 21, (*Hector*) 112, fig. 132.
85 (83) Sarda chilensis.
Pelamys chilensis (*C. and V.*) *Hutton*, Fishes N. Z., p. 22.
86 (82) Lepidothynnus huttoni.
Lepidothynnus huttoni *Günth.*, Report on Pelagic Fishes of *Challenger*, p. 15, pl. 6, fig. A.

51. GEMPYLIDÆ.

87 (59) Thyrsites atun.
Thyrsites atun (*Euphrasen*) *Hutton*, Fishes N. Z., pp. 13, (*Hector*) 109, fig. 20.
88 (60) Promethichthys prometheus.
Thyrsites prometheus (*W. and R.*) vel T. prometheoides (*Bleeker*) *Hector*, Trans. N. Z. Inst., vol. XVI, p. 322.

52. LEPIDOPIDÆ.

89 (57) Lepidopus caudatus.
Lepidopus caudatus (*Euphrasen*) *Hutton*, Fishes N. Z., pp. 13, (*Hector*) 109, fig. 19; *Robson*, Trans. N. Z. Inst., vol. VIII, p. 218.
90 (58) Benthodesmus elongatus.
Lepidopus elongatus *Clarke*, Trans. N. Z. Inst., vol. XI, p. 294, pl. 14, (2 f.).

53. HISTIOPHORIDÆ.

91 (56) Histiophorus herschelii.
Histiophorus herschelii (*Gray*) *Hutton*, Cat. Fishes N. Z., p. 14; *Hutton*, Trans. N. Z. Inst., vol. II, p. 13, pl. f.; vol. VIII, p. 216.

54. XIPHIIDÆ.

92 (55) Xiphias gladius.
Ziphius gladius (*Linn*) *Hector*, Trans. N. Z. Inst., vol. VII, p. 246; vol. VIII, p. 219.
Xiphias gladius *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 211.

55. LAMPRIDIDÆ.

93 (78) Lampris guttatus.
Lampris luna (*Risso*) *Hector*, Trans. N. Z. Inst., vol. XVI, p. 322.

56. ZEIDÆ.

94 (72) Zeus faber.
Zeus faber (*L.*) *Hutton*, Fishes N. Z., pp. 18, (*Hector*), 111, fig. 27.
95 (74) Cyttus australis.
Cyttus australis (*Rich.*) *Hutton*, Fishes N. Z., pp. 19, (*Hector*) 112, fig. 28.
96 (73) Cyttus novæ-zelandiæ.
Zeus novæ-zelandiæ *Arthur*, Trans. N. Z. Inst., vol. XVII, p. 163, pl. 14, f. 3.
97 (75) Rhombocyttus traversi.
Cyttus traversi *Hutton*, Fishes N. Z., p. 19; Trans. N. Z. Inst., vol. V, p. 261, pl. 9, f.

57. CAPROIDÆ.

98 (76) Capromimus abbreviatus.
Platystethus abbreviatus *Hector*, Trans. N. Z. Inst., vol. VII, p. 247, pl. 11, f.
Capros abbreviatus *Hector*, Trans. N. Z. Inst., vol. IX, p. 465.
Cyttus abbreviatus *Hutton*, Trans. N. Z. Inst., vol. XXII, p. 279.

58. TEUTHIDIDÆ.

99 (61) Teuthis triostegus.
Acanthurus triostegus (*L.*) *Hutton*, Cat. Fishes N. Z., p. 15.

59. SERRANIDÆ.

100 (23) Pseudanthias lepidopterus.
Scorpis hectori *Hutton*, Fishes N. Z., pp. 4, (*Hector*) 106, fig. 4.
Anthias lepidoptera *Hutton*, Trans. N. Z. Inst., vol. IX, p. 353.

101 (24) Pseudanthias longimanus.
Scorpis hectori *Hutton*, Trans. N. Z. Inst., vol. V, p. 259, pl. 7, f.
Scorpis fairchildi *Hector*, Trans. N. Z. Inst., vol. VII, p. 241.

102 (25) Gilbertia huntii.
Plectropoma huntii *Hector*, Trans. N. Z. Inst., vol. VII, p. 241, pl. 10, f.

103 (26) Polyprion prognathus.
Oligorus gigas (*Owen*) *Hutton*, Fishes N. Z., pp. 1, (*Hector*) 102, fig. 1.
Oligorus gadoides (*Sol.*) *Hutton*, Trans. N. Z. Inst., vol. V, p. 259.
Polyprion prognathus (*Forster*) *Günther*, Ann. and Mag. Nat. Hist., (5) vol. XX, p. 236.

60. LUTJANIDÆ (?).

104 (28) Plagiogeneion rubiginosus.
Therapon ? rubiginosus *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 209.

61. ARRIPIDIDÆ.

105 (29) Emmelichthys nitidus.
Erytrichthys nitidus (*Richardson*) *Hutton*, Fishes N. Z., p. 3.

106 (30) Arripis trutta.
Arripis salar (*Rich.*) *Hutton*, Fishes N. Z., pp. 2, (*Hector*) 105, fig. 2.

62. PENTACEROTIDÆ.

107 (27) Pseudopentaceros richardsonii.
Pentaceros richardsonii (*Smith*) *Hutton*, Trans. N. Z. Inst., vol. XXII, p. 277.

63. KYPHOSIDÆ or PIMELEPTERIDÆ.

108 (31) Atypichthys strigatus.
Atypus strigatus (*Günth.*) *Kirk*, Trans. N. Z. Inst., vol. XII, p. 308.

109 (33) Incisidens simplex.
Girella percoides *Hector*, Trans. N. Z. Inst., vol. VII, p. 243, pl. 10, f.
Girella simplex (*Rich.*) *Hector*, Trans. N. Z. Inst., vol. IX, p. 468, pl. 8, f.
Pimelepterus drewii *Hector*, Trans. N. Z. Inst., vol. XIX, p. 590.
Ctenolabrus ? knoxii *Hutton*, Trans. N. Z. Inst., vol. V, p. 265, 308, pl. 10, f.

64. SPARIDÆ.

110 (35) Sparosomus auratus.
Pagrus unicolor (*Quoy* and *Gaim.*) *Hutton*, Fishes N. Z., pp. 6, (*Hector*) 106, fig. 7; Trans. N. Z. Inst., vol. IX, p. 353.

65. MULLIDÆ.*

111 (32) Upeneichthys vlamingii.
Upeneoides vlamingii *Hutton*, Fishes N. Z., p. 5.
Upeneichthys vlamingii *Hutton*, Proc. N. Z. Inst., vol. IX, p. 465, pl. 9, f.

66. POMACENTRIDÆ.

112 (135) Dascyllus aruanus.
Dascyllus aruanus (*L.*) *Hutton*, Fishes N. Z., p. 42.

67. LABRIDÆ.

113 (136) Lepidaplois oxycephalus.
Cossyphus unimaculatus (*Günth.*) *Hector*, Trans. N. Z. Inst., vol. XVI, p. 323.

114 (——) Duymæria flagellifera?
Duymæria flagellifera (*T. and S.*) *Hector*, Trans. N. Z. I., vol. XXII, p. 527, 1890.

115 (137) Pseudolabrus fucicola.
Labrichthys bothryocosmus (*Rich.*) *Hutton*, Fishes N. Z., pl. 7 (fig. only).
Labrichthys fucicola (*Rich.*) *Hutton*, Trans. N. Z. Inst., vol. V, p. 265.

116 (——) Pseudolobrus roseipunctatus.
Labrichthys roseipunctatus *Hutton*, Trans. N. Z. I., vol. XII, p. 455.

117 (138) Pseudolabrus bothryocosmus.
Labrichthys bothryocosmus (*Rich.*) *Hutton*, Fishes N. Z., p. 43 (not fig.); *Hutton*, Trans. N. Z. Inst., vol. V, p. 265, pl. 10, f.

*Upeneichthys porosus (*C. and V.*) *Hutton*, Fishes N. Z., p. 5, has been since eliminated by Prof. Hutton.

118 (139) Pseudolabrus miles.
Labrichthys psittacula (*Rich.*) *Hutton*, Fishes N. Z., p. 43; Trans. N. Z. Inst., vol. IV, p. 265, pl. 10, f.
Labrichthys coccinea (*Forst.*) *Hutton*, Trans. N. Z. Inst., vol. IX, p. 354.

119 (140) Pseudolabrus celidotus.
Labrichthys celidotus (*Forst.*) *Hutton*, Fishes N. Z., p. 42; *Günther*, Ann. and Mag. Nat. Hist., (4) vol. XVII, p. 398.

120 (141) Pseudolabrus cinctus.
Labrichthys cincta *Hutton*, Trans. N. Z. Inst., vol. IX, p. 351.

121 (142) Pseudolabrus laticlavius.
Labrichthys laticlavius (*Rich.*) *Hector*, Trans. N. Z. Inst., vol. XVI, p. 323.

122 (143) Cymolutes sandeyeri.
Cymolutes sandeyeri *Hector*, Trans. N. Z. Inst., vol. XVI, p. 323.

68. ODACIDÆ.

123 (144) Odax vittatus.
Odax vittatus (*Sol.*) *Hutton*, Fishes N. Z. p. 13; *Hutton*, Trans. N. Z. Inst., vol. V, p. 266; pl., vol. VIII, p. 244; vol. XII, p. 310; *Arthur*, vol. XVII, p. 169, pl. 14, f. 7.

124 (145) Coridodax pullus.
Coridodax pullus (*Forst.*) *Hutton*, Fishes N. Z., pp. 44, (*Hector*) 114, fig. 71; *Knox*, Trans. N. Z. Inst., vol. III, p. 130, pl. 18, f. 2.

69. HAPLODACTYLIDÆ.

125 (34) Haplodactylus meandratus.
Chironemus georgianus *Hutton*, Fishes N. Z., p. 7.
Haplodactylus meandratus (*Rich.*) *Hector*, Trans. N. Z. Inst., vol. VII, p. 241, pl. 10, f.; *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 211.
Haplodactylus donaldi *Haast*, Trans. N. Z. Inst., vol. V, p. 272, pl. 16, f.

126 (36) Chironemus furgussoni.
Haplodactylus fergussoni *Hector*, Trans. N. Z. Inst., vol. VII, p. 243.
Haplodactylus furgussoni *Hector*, Trans. N. Z. Inst., vol. IX, p. 467, pl. 8, f.

127 (—) Goniistius zonatus.
Chilodactylus zonatus (*Cur.* and *Val.*) *Hector*, Trans. N. Z. I. Inst., vol. XXII, p. 527, 1890.

128 (37) Chilodactylus macropterus.
Chilodactylus macropterus (*Forst.*) *Hutton*, Fishes N. Z., pp. 8, (*Hector*) 107, fig. 10.

129 (38) Chilodactylus spectabilis.
Chilodactylus spectabilis *Hutton*, Fishes N. Z., p. 8; Trans. N. Z. Inst., vol. V, p. 259, pl. 7, f.

130 (39) Chilodactylus douglasi.
Chilodactylus douglasi *Hector*, Trans. N. Z. Inst., vol. VII, p. 241, pl. 10, f.

131 (40) Chilodactylus carponemus.
Chilodactylus carponemus (*Günth.*) *Hutton*, Fishes N. Z., p. 7.

132 (41) Mendosoma lineata.
Mendosoma lineata *Hutton*, Trans. N. Z. Inst., vol. V, p. 260, pl. 7, f. (excl. syn. part.).
Mendosoma lineatum (*Gay*) *Hutton*, Trans. N. Z. Inst., vol. IX, p. 353.

133 (42) Latris lineata.
Sciæna lineata *Forster*.
Latris hecateia (*Rich.*) *Hutton*, Fishes N. Z., p. 8, (*Hector*) 107, fig. 12.

134 (43) Latris ciliaris.
Latris ciliaris (*Forst.*) *Hutton*, Fishes N. Z., p. 9, (*Hector*) 108, fig. 13.

135 (44) Latris ærosa.
Latris ærosa *Hutton*, Trans. N. Z. Inst., vol. IX, p. 353.

70. SCORPAENIDÆ.

136 (45) Sebastapistes percoides.
Sebastes percoides (*Solander*) *Hutton*, Fishes N. Z., p. 9, (*Hector*) 108; *Hutton*, Trans. N. Z. Inst., vol. V, p. 261, pl. 8, f.; *Hutton*, Trans. N. Z. Inst., vol. IX, p. 353.

137 (47) Sebastapistes barathri.
Scorpaena barathri *Hector*, Trans. N. Z. Inst., vol. VII, p. 245, pl. 9, f.

138 (46) Scorpaena cottoides.
Scorpaena cruenta (*Solander*) *Hutton*, Fishes N. Z., p. 9; *Hutton*, Trans. N. Z. Inst., vol. V, p. 261, pl. 8, f.

139 (48) Scorpaena bysoensis.
Scorpaena bysoensis (*Rich.*) *Hector*, Trans. N. Z. Inst., vol. XVI, p. 323.

140 (50) Cottapistus cottoides.
Prosopodasys cottoides (*L.*) *Hutton*, Fishes N. Z., p. 11.

71. COTTIDÆ.*

141 (100) Neophrynichthys latus.

Psychrolutes latus *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 214.

Neophrynichthys latus *Günth.*, Ann. and Mag. Nat. Hist. (4), v. XVII, p. 395; *Arthur*, Trans. N. Z. Inst., vol. XVII, p. 166, pl. 14, f. 5, 5a; *Gill*, Proc. U. S. Nat. Mus., vol. XI, p. 327, pl. 41.

72. CONGIOPODIDÆ.

142 (49) Congiopodus leucopœcilus.

Agriopus leucopœcilus (*Rich.*) *Hutton*, Fishes N. Z., p. 11; *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 211.

73. PERCOPHIDÆ.

143 (90) Parapercis colias.

Percis colias (*Forst.*) *Hutton*, Fishes N. Z., p. 25, (*Hector*) 113, fig. 38.

144 (91) Parapercis gilliesii.

Percis gilliesii *Hutton*, Ann. and Mag. Nat. Hist. (5), vol. III, p. 53.

145 (93) Cheimarrichthys forsteri.

Cheimarrichthys forsteri *Haast*, Trans. N. Z. Inst., vol. VI, p. 103, pl. 18, f. [4].

74. NOTOTHENIIDÆ.

146 (94) Notothenia maoriensis.

Notothenia coriiceps (*Rich.?*) *Hutton*, Fishes N. Z., p. 26.

Notothenia maoriensis *Haast*, Trans. N. Z. Inst , vol. V, p. 276, pl. 16, f.; vol. VIII, p. 212.

147 (95) Notothenia angustata.

Notothenia angustata *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 213.

148 (96) Notothenia cornucola.

Notothenia cornucola (*Rich.*) *Hutton*, Fishes N. Z., p. 26; *Hutton*, Trans. N. Z. Inst., vol. V, p. 262.

149 (97) Notothenia arguta.

Notothenia arguta *Hutton*, Trans. N. Z. Inst., vol. XI, p. 339.

150 (98) Notothenia microlepidota.

Notothenia microlepidota *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 213.

151 (99) Notothenia parva.

Notothenia parva *Hutton*, Trans. N. Z. Inst., vol. XI, p. 339.

75. BOVICHTHYIDÆ.

152 (92) Bovichthys variegatus.

Bovichthys variegatus (*Rich.?*) *Hutton*, Fishes N. Z., p. 24; *Hutton*, Trans. N. Z. Inst., vol. V, p. 262.

76. URANOSCOPIDÆ.

153 (85) Genyagnus maculatus.

Uranoscopus maculatus (*Forster*) *Rich.*

Kathetostoma monopterygium (*Bloch*) *Hutton*, Fishes N. Z., p. 23; Trans. N. Z. Inst., vol. V, p. 104.

Synnema monopterygium *Haast*, Trans. N. Z. Inst., vol. V, p. 274.

Anema monopterygium *Hutton*, Trans. N. Z. Inst., vol. XXII, p. 279; *Günther*, Ann. and Mag. Nat. Hist. (4), vol. XVII, p. 394.

Kathetostoma giganteum *Haast*, Trans. N. Z. Inst., vol. V, p. 274, pl. 16, f.

154 (86) Kathetostoma lævis.

Kathetostoma lævе (*Bloch*) *Hutton*, Fishes N. Z., p. 23.

155 (87) Kathetostoma fluviatilis.

Kathetostoma fluviatilis *Hutton*, Fishes N. Z., p. 24.

77. LEPTOSCOPIDÆ.

156 (88) Leptoscopus macropygus.

Leptoscopus huttonii *Haast*, Trans. N. Z. Inst., vol. V, p. 275, pl. 16, f.

Leptoscopus tricolor *Haast*, Trans. N. Z. Inst., vol. V, p. 276.

Leptoscopus macropygus (*Rich*) *Hutton*, Trans. N. Z. Inst., vol. VI, p. 106; *Günther*, Ann. and Mag. Nat. Hist. (4), vol. XVII, p. 394.

157 (89) Crapatalus novæ-zelandiæ.

Crapatalus novæ-zelandiæ *Günther*, Ann. and Mag. Nat. Hist. (3), vol. VII, p. 87; *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 212.

Leptoscopus (?) angusticeps *Hutton*, Trans. N. Z. Inst., vol. VI, p. 106, f.

Leptoscopus robsoni *Hector*, Trans. N. Z. Inst., vol. VII, p. 248.

Leptoscopus canis *Arthur*, Trans. N. Z. Inst., vol. XVII, p. 165, pl. 14, f. 4.

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* The Triglidæ are doubtless genetically related to the mail-cheeked acanthopterygians, but deviate so much by the crowding out of place of the posterotemporals, and the dissolution of the posttemporals from the scapular arch and their intimate union with the cranium, that they are isolated in a special suborder, and consequently have to take a different place in the system (178–180).

78. HEMEROCŒTIDÆ.

158 (108) Hemerocœtes acanthorhynchus.
Hemerocœtes acanthorhynchus (*Forst.*) *Hutton*, Fishes N. Z., p. 37.

79. GOBIIDÆ.

159 (106) Gobiomorphus gobioides.
Eleotris gobioides (*C. and V.*) *Hutton*, Fishes N. Z., p. 29; *Hutton*, Trans. N. Z. Inst., vol. v, p. 263, pl. 15, f.

160 (107) Eleotris radiata.
Eleotris radiata (*Quoy and Gaim.*) *Hutton*, Trans. N. Z. Inst., vol. v, p. 263, pl. 9, f.

161 (105) Gobius lentiginosus.
Gobius lentiginosus (*Rich.*) *Hutton*, Fishes N. Z., p. 29.

80. CLINIDÆ.

162 (109) Ericentrus rubrus.
Stichæus rubrus *Hutton*, Fishes N. Z., p. 33.
Clinus rubrus *Hutton*, Trans. N. Z. Inst., vol. v, p. 261, pl. 9, f.

163 (110) Cologrammus flavescens.
Stichæus flavescens *Hutton*, Fishes N. Z., p. 33.
Clinus flavescens *Hutton*, Trans. N. Z. Inst., vol. v, p. 264, pl. 15, f.

164 (111) Cristiceps australis.
Cristiceps australis (*C. and V.*) *Hutton*, Trans. N. Z. Inst., vol. v, p. 264.

165 (112) Tripterygion tripinne.
Tripterygium forsteri (*C. and V.*) *Hutton*, Fishes N. Z., p. 31.
Tripterygium forsteri *Hutton*, Trans. N. Z. Inst., vol. IX, p. 354.

166 (113) Tripterygion decemdigitatum.
Tripterygium decemdigitatus *Clarke*, Trans. N. Z. Inst., vol. XI, p. 292, pl. 15, f.

167 (114) Tripterygion medium.
Tripterygium medium (*Günth.*) *Hutton*, Fishes N. Z., p. 32.

168 (115) Tripterygion dorsale.
Tripterygium dorsalis *Clarke*, Trans. N. Z. Inst., vol. XI, p. 291, pl. 15, f.

169 (116) Tripterygion varium.
Tripterygium varium (*Forst.*) *Hutton*, Fishes N. Z., p. 33; Trans. N. Z. Inst., vol. XXII, p. 280.
Tripterygium nigripenne (*C. and V.*) *Hutton*, Fishes N. Z., p. 31; Trans. N. Z. Inst., vol. V, p. 263; vol. IX, p. 354.

170 (117) Tripterygion robustum.
Tripterygium robustum, *Clarke*, Trans. N. Z. Inst., vol. XI, p. 292, pl. 15, f.
Tripterygium jenningsi *Hutton*, Trans. N. Z. Inst., vol. XI, p. 339.

171 (118) Notoclinus fenestratus.
Tripterygium fenestratum (*Forst.*) *Hutton*, Fishes N. Z., p. 32.
Anchenopterus fenestratus (*Forst.*) *Hutton*, Trans. N. Z. Inst., vol. XXII, p. 281.
Tripterygium compressum *Hutton*, Trans. N. Z. Inst., vol. V, p. 263, pl. 15, f.; vol. VIII, p. 214; *Arthur*, Trans. N. Z. Inst., vol. XVII, p. 168, pl. 14, f. 6.
Anchenopterus compressus *Hutton*, Trans. N. Z. Inst., vol. IX, p. 354.

81. ACANTHOCLINIDÆ.

172 (119) Acanthoclinus litoreus.
Acanthoclinus littoreus (*Forst.*) *Hutton*, Fishes N. Z., p. 34.

173 (120) Acanthoclinus taumaka.
Acanthoclinus taumaka *Clarke*, Trans. N. Z. Inst., vol. XI, p. 293, pl. 15, f.

82. GADOPSIDÆ.

174 (157) Gadopsis marmoratus.
Gadopsis marmoratus (*Rich.*) *Hutton*, Trans. N. Z. Inst., vol. XXII, p. 282 (fide "*Rich.*; Ann. Mag. Nat. Hist., ser. 4, vol. I, p. 342."—Reference erroneous—See *Hector*, Trans. N. Z. Inst., vol. IX, p. 467).

83. LYCODIDÆ.

175 (146) Hypolycodes haastii.
Hypolycodes haastii *Hector*, Trans. N. Z. Inst., vol. XIII, p. 194.

84. BROTULIDÆ.

176 (155) Dinematichthys consobrinus.
Dinematichthys consobrinus *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 217; *Hector*, Trans. N. Z. Inst., vol. IX, p. 466, pl. 9, f.

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*Gobius amiciensis (*C. and V.*) *Hutton*, Fishes N. Z. p. 29, eliminated afterwards by *Hutton*, Trans. N. Z. Inst., vol. V, p. 263, as an inhabitant of New Ireland. The generic relations of *Eleotris radiata* are unknown.

85. OPHIDIIDÆ.*

177 (156) **Genypterus blacodes.**
Genypterus blacodes (*Forst.*) *Hutton*, Fishes N. Z., pp. 48, (*Hector*) 116, f. 77.

Suborder CRANIOMI.

86. TRIGLIDÆ.

178 (104) **Trigla kumu.**
Trigla kumu (*Less. and Garn.*) *Hutton*, Fishes N. Z., pp. 28, (*Hector*) 113, fig. 42.

179 (——) **Lepidotrigla vanessa.**
Trigla vanessa (*Rich.*) *Hector*, Trans. N. Z. Inst., vol. XXII, p. 530, 1890.

180 (103) **Lepidotrigla brachyptera.**
Lepidotrigla brachyoptera *Hutton*, Fishes N. Z., p. 27; *Hutton*, Trans. N. Z. Inst., vol. V, p. 263, pl. 15, f.

Suborder TÆNIOSOMI.

87. TRACHYPTERIDÆ.

181 (132) **Trachypterus altivelis.**
Trachypterus altivelis (*Kner?*) *Hutton*, Trans. N. Z. Inst., vol. V, p. 264; vol. VIII, p. 214.

182 (133) **Trachypterus arawata.**
Trachypterus arawata *Clarke*, Trans. N. Z. Inst., vol. XIII, p. 195, fig.

88. REGALECIDÆ.

183 (130) **Regalecus pacificus**
Regalecus pacificus *Haast*, Trans. N. Z. Inst., vol. X, p. 247, pl. 7; *Powell*, Trans. N. Z. Inst., vol. XI, p. 269.
Regalecus gladius (*Walb.*) *Hutton*, Fishes N. Z., p. 35.

184 (131) **Regalecus argenteus.**
Regalecus argenteus *Parker*, Trans. N. Z. Inst., vol. XVI, p. 284, pl. 23, 24; vol. XX, p. 20.

—— (——) **Regalecus ——.**
Regalecus grilli (*Lindroth*) *Forbes*, Trans. N. Z. Inst., vol. XXIV, p. 193.

Suborder XENOPTERYGII.

89. GOBIESOCIDÆ.

185 (126) **Diplocrepis puniceus.**
Diplocrepis puniceus (*Rich.*) *Hutton*, Fishes N. Z., p. 40; *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 214.

186 (127) **Trachelochismus pinnulatus.**
Trachelochismus pinnulatus (*Forst.*) *Hutton*, Fishes N. Z., p. 40; *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 214.

187 (128) **Trachelochismus guttulatus.**
Trachelochismus guttulatus *Hutton*, Fishes N. Z., p. 41.

188 (129) **Crepidogaster hectoris.**
Crepidogaster hectoris *Günth.*, Ann. and Mag. Nat. Hist. (4), vol. XVII, p. 396; Trans. N. Z. Inst., vol. IX, p. 471.

Suborder DISCOCEPHALI.

90. ECHENEIDIDÆ.

189 (84) **Remora brachyptera.**
Echeneis brachyptera (*Lowe*) *Hutton*, Trans. N. A. Inst., vol. VIII, p. 217.

Suborder ANACANTHINI.

91. GADIDÆ.

190 (152) **Lotella rhacina.**
Lotella rhacinus (*Forst.*) *Hutton*, Fishes N. Z., p. 46; *Hutton*, Trans. N. Z. Inst., vol. V, p. 266; vol. VI, (opp. p. 104), pl. 18, f.

191 (150) **Pseudophycis bachus.**
Pseudophycis bachus (*Forst.*) *Hutton*, Fishes N. Z., pp. 46, (*Hector*) 115, fig. 75.

192 (151) **Pseudophycis breviusculus.**
Pseudophycis breviusculus (*Rich.*) *Hutton*, Fishes N. Z., p. 47, fig. 76.

* The ophidioidean fishes are naturally related to the blennioidean, and have no special characters in common with the gadoidean and only a vague external resemblance.

193 (149) **Halargyreus johnsonii.**
Halargyreus johnsonii (*Günth.*) *Hutton*, Fishes N. Z., p. 45.

194 (153) **Onos novæ-zelandiæ.**
Motella novæ-zealandiæ *Hector*, Trans. N. Z. Inst., vol. VI, p. 107, pl. 18, f.

195 (147) **Bathygadus cottoides.**
Bathygadus cottoides *Günth.*, Ann. and Mag. Nat. Hist. (5), vol. II, p. 23; Report on Deep-sea Fishes of *Challenger*.

92. MERLUCIIDÆ.

196 (148) **Merlucius gayi.**
Gadus australis *Hutton*, Fishes N. Z., pp. 45, (*Hector*) 115, fig. 72.
Merlucius gayi ? *Hutton*, Trans. N. Z. Inst., vol. V, p. 265.

93. BREGMACEROTIDÆ.

197 (154) **Auchenoceros punctatus.**
Calloptilum punctatum *Hutton*, Trans. N. Z. Inst., vol. V, p. 267, pl. 11, f.
Bregmaceros punctatus *Günther*, Ann. and Mag. Nat. Hist. (4), vol. XVII, p. 398.
Auchenoceros punctatus *Günth.*, Report on Pelagic Fishes of *Challenger*, p. 26, pl. 3.

94. MACRURIDÆ.

198 (161) **Macruronus novæ-zealandiæ.**
Coryphænoides novæ-zealandiæ (*Hector*) *Hutton*, Fishes N. Z., p. 49, fig. 79; *Hector*, Trans. N. Z. Inst., vol. V, p. 267.

199 (160) **Trachyrhynchus longirostris.**
Macrurus longirostris *Günth.*, Ann. and Mag. Nat. Hist. (5), vol. II, p. 23.

200 (159) **Nematonurus armatus.**
Macrurus armatus *Hector*, Trans. N. Z. Inst., vol. VII, p. 249, pl. 11, f.

201 (162) **Optonurus denticulatus.**
Coryphænoides denticulatus (*Rich.*) *Hutton*, Fishes N. Z., p. 49, fig. 80.

202 (163) **Chalinura murrayi.**
Coryphænoides murrayi *Günth.*, Ann. and Mag. Nat. Hist. (5), vol. II, p. 26.

203 (164) **Macrurus serrulatus.**
Coryphænoides serrulatus *Günth.*, Ann. and Mag. Nat. Hist. (5), vol. II, p. 26.

204 (158) **Cœlorhynchus australis.**
Macrurus australis (*Rich.*) *Hutton*, Fishes N. Z., p. 49, fig. 78; Trans. N. Z. Inst., vol. V, p. 267.

Suborder HETEROSOMATA.

95. PLEURONECTIDÆ.

205 (166) **Caulopsetta scaphus.**
Pseudorhombus scaphus (*Forst.*) *Hutton*, Fishes N. Z., p. 51, f. 82.

206 (167) **Caulopsetta boops.**
Pseudorhombus boops *Hector*, Trans. N. Z. Inst., vol. VII, p. 249, pl. 11, f.

207 (165) **Brachypleura novæ-zealandiæ.**
Brachypleura novæ-zealandiae (*Günth.*) *Hutton*, Fishes N. Z., p. 50.

208 (168) **Ammotretis rostratus.**
Ammotretis rostratus (*Günth.*) *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 215.

209 (169) **Ammotretis guentheri.**
Ammotretis güntheri *Hutton*, Trans. N. Z. Inst., vol. V, p. 267, pl. 11, f.

210 (170) **Rhombosolea plebeia.**
Rhombosolea monopus (*Günth.*) *Hutton*, Fishes N. Z., pp. 51, (*Hector*) 117, fig. 83.
Bowenia novæ-zealandiæ *Haast*, Trans. N. Z. Inst., vol. V, p. 277, pl. 16, f.

211 (171) **Rhombosolea flesoides.**
Rhombosolea leporina (*Günth.*) *Hutton*, Trans. N. Z. Inst., vol. V, p. 268, pl. 11, f.
Rhombosolea flesoides *Günth.*, Ann. and Mag. Nat. Hist. (3), vol. XI, p. 117; *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 215.

212 (172) **Rhombosolea tapirina.**
Rhombosolea tapirina (*Günth.*), Ann. and Mag. Nat. Hist. (4), vol. XVII, p. 399; *Hector*, Trans. N. Z. Inst., vol. VI, p. 106; *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 215.

213 (173) **Rhombosolea retiaria.**
Rhombosolea tapirina (*Günth.*) *Hector*, Trans. N. Z. Inst., vol. V, p. 268, pl. 13, f.
Rhombosolea retiaria *Hutton*, Trans. N. Z. Inst., vol. VI, p. 107.

214 (174) **Peltorhamphus novæ-zealandiæ.**
Peltorhamphus novæ-zealandiae (*Günth.*) *Hutton*, Fishes N. Z., p. 52, fig. 84.

Order HEMIBRANCHII.

96. MACRORHAMPHOSIDÆ.

215 (125) Centriscops humerosus.
Centriscus humerosus (*Rich.*) *Hutton*, Fishes N. Z., p. 38.

Order LOPHOBRANCHII.

97. SYNGNATHIDÆ.

216 (209) Siphostoma pelagica.
Syngnathus pelagicus (*L.*) *Hutton*, Fishes N. Z., p. 67.

217 (210) Siphostoma blainvilliana.
Syngnathus blainvillianus (*Eydoux* and *Soul.*) *Hutton*, Trans. N. Z. Inst., vol. IX, p. 472; *Günther*, Ann. and Mag. Nat. Hist. (4), vol. XVII, p. 402, 1876.

218 (211) Doryichthys elevatus.
Doryichthys elevatus *Hutton*, Fishes N. Z., p. 68.

219 (212) Ichthyocampus filum.
Ichthyocampus filum (*Günth.*) *Hutton*, Fishes N. Z., p. 68.

220 (213) Stigmatophora longirostris.
Stigmatophora longirostris *Hutton*, Fishes N. Z., p. 69; *Hutton*, Trans. N. Z. Inst., vol. VIII, p. 216.

98. HIPPOCAMPIDÆ.

221 (214) Solegnathus spinosissimus.
Solenognathus spinosissimus (*Günth.*) *Hutton*, Fishes N. Z., p. 69; *Hutton*, Trans. N. Z. Inst., vol. V, p. 271.

222 (215) Hippocampus abdominalis.
Hippocampus abdominalis (*Lesson*) *Hutton*, Fishes N. Z., p. 70.

Order PLECTOGNATHI.

99. BALISTIDÆ.

223 (216) Monacanthus scaber.
Monacanthus convexirostris (*Günth.*) *Hutton*, Fishes N. Z., p. 71, fig. 114; Trans N. Z. Inst., vol. V, p, 271; vol. IX, p. 354 (identified with *Balistes scaber*, F.)

100. OSTRACIONTIDÆ.

224 (217) Ostracion fornasini.
Ostracion fornasini (*Bianc.?*) *Hutton*, Fishes N. Z., p. 71.
Aracana aurita (*Shaw*) *Hutton*, Trans. N. Z. Inst., vol. V, p. 271.

101. TETRAODONTIDÆ.

225 (218) Amblyrhynchotus richei.
Tetrodon richei (*Freminv.*) *Hutton*, Fishes N. Z., p. 72.

102. DIODONTIDÆ.

226 (219) Dicotylichthys jaculiferus.
Chilomycterus jaculiferus (*Cuv.*) *Hutton*, Fishes N. Z., p. 73.
Dicotylichthys jaculiferus *Hutton*, Trans. N. Z. Inst., vol. V, p. 271.

103. MOLIDÆ.

227 (220) Mola mola.
Orthagoriscus truncatus *Hutton*, Fishes N. Z., p. 73.
Orthagoriscus mola (*L.*) *Hutton*, Trans. N. Z. Inst., vol. V, p. 271; vol. 18, p. 135.

Order PEDICULATI.

104. ANTENNARIIDÆ.

228 (101) Saccarius lineatus.
Saccarius lineatus (*Günth.*) *Hutton*, Fishes N. Z., p. 30.

105. CERATIIDÆ.

229 (102) Ægeonichthys appellii.
Ægeonichthys appellii *Clarke*, Trans. N. Z. Inst., vol. X, p. 245, pl. 6, (5 fig.).

NOTES.

The reasons for most of the numerous changes in nomenclature apparent in the previous catalogue will be obvious to those who are sufficiently acquainted with the literature of ichthyology. There are, however, a number of new generic names, which may be indicated in the following notes, with the reasons in brief for giving them. The numbers prefixed refer to those in the preceding catalogue.

NOTE 1 (46–49).—The scopeloid fishes have been examined recently by Drs. Goode and Bean, who have had large collections to base their researches upon. Dr. Goode has kindly given me the results of his investigations, and the species enumerated in the catalogue have been named on his authority. *Lampadena* is a new genus, established by Drs. Goode and Bean, and will be published in their forthcoming work on deep-sea fishes.

NOTE 2 (51, 52).—The leptocephaloid fishes enumerated are the mature forms. Larval forms, however, appear in Prof. Hutton's list under the following names and numbers:

225. LEPTOCEPHALUS LONGIROSTRIS (*Kaup*) *Haast*, Trans. N. Z. Inst., vol. VII, 238, 1875.

226. LEPTOCEPHALUS ALTUS (*Rich.*) *Hutton*, Trans. N. Z. Inst., vol. VIII, 215, 1876.

One (225) may be the larva of the *conger* and the other (226) of the *Congermuræna*, but the identification is extremely doubtful, and can only be effected when more data are at hand.

NOTE 3 (79).—The *Platystethus huttonii* of Günther does not belong to the genus so named by that naturalist, but is distinguished by the many-rayed first dorsal (13 spines); it may therefore be called EVISTIUS (< *ευ*, augmentative + *ἱστίον*, sail). The "*Platystethus cultratum*" can not retain that name, as *Platystethus* had been used long previously by Mannerheim (1830) and Erichson (1840) for a genus of beetles; it may be called BATHYSTETHUS (*βαθύς*, deep) CULTRATUS.

NOTE 4 (88).—The generic name *Promethens* having been used by Hubner for a group of lepidopterous insects in 1822–'26, the genus called by the same name in 1839 by Lowe must receive another, and, to make the change as little as possible, may be called *Promethichthys* (<*προμηθής*, wary + *ιχθύς*, fish).

NOTE 5 (94–98).—Most of the *Zeidæ* of New Zealand are destitute of the shields which are characteristic of *Zeus*.

Cyttus has a form resembling that of *Zeus*, and is represented by the two species *C. australis* and *C. novæ-zelandiæ*.

Rhombocyttus is nearly related to *Cyttus*, but is distinguished by its angulated high rhombiform body and elongated filiform dorsal spines as well as ventral rays. The only species is *R. traversi*

Capromimus has the aspect of the genus *Capros* and has an oblong subrhombiform body. 7 pungent dorsal spines, dorsal and anal increasing backwards, and ventrals with 6 rays besides the spine. The only species is *C. abbreviatus* = *Platystethus abbreviatus* Hector. Possibly the genus may prove not to be a caproid when anatomically examined.

NOTE 6 (110).—*Sparosomus auratus* is more different from *Pagrus* than that group (represented by its type) is from *Sparus* or *Pagellus*, and is differentiated by the obsolescence of the inner lateral crests.

NOTE 7 (162).—The *Stichæum rubrum* or *Clinus rubrus* of Hutton is distinguished from other fishes by the combination of a form like that of *Clinus* with a dorsal having many spines (about 40) and only about 1 ray. It is therefore named *Ericentrus rubrus* (<*ερι*, augmentative + *κεντρον*, spine); *rubrus* is accepted from Prof. Hutton, as it is an alternative (although rare) for *ruber*.

NOTE 8 (163).—The *Stichaeum flavescens* or *Clinus flavescens* of Hutton is differentiated from other types (and especially *Ericentrus*) by the form, more nearly even dorsal with a short-rayed portion (about 38 spines + 6 rays), and imperfect lateral line; it may appropriately be designated as *Cologrammus* (κολος, curtailed + γραμμα, line).

NOTE 9 (171).—The *Tripterygion fenestratum* of most authors appears to be distinguished from the typical species of *Tripterygion* by the less divided dorsal with a shorter median portion and by the form of the sub-perculum, as well as general aspect. It may therefore be called *Notoclinus fenestratus.*

NOTE 10 (205, 206).—The *Pleuronectes scaphus* of Forster and *Pseudorhombus boops* of Hector constitute a peculiar genus, viz:

CAULOPSETTA.—Psettine Pleuronectids with "teeth rather large, conical, pointed, the lateral ones of the upper jaw the shortest," lateral line with a distinct arch in front, "scales ctenoid," mouth moderate, interorbital area very narrow, and numerous dorsal and anal rays. (<Καυλός, stalk quasi ray + Ψητα, flatfish, in analogy with *Polycaulus* Günther.)

Type *C. scaphus* = *Pseudorhombus scaphus* (Forst.) Hutton.

The genus is apparently related to *Arnoglossus*, *Syacium*, and *Citharichthys* rather than to *Paralichthys* (= *Pseudorhombus*). The long base of the ventral on the ridge of the abdomen, the comparatively short mandible, and the absence of any caudal constriction widely separate it from *Pseudorhombus* or *Paralichthys.*

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FAMILIES AND SUBFAMILIES OF FISHES.

FAMILIES AND SUBFAMILIES OF FISHES.

By Theodore Gill.

In 1872, the present author published an "Arrangement of the Families of Fishes, or Classes Pisces, Marsipobranchii, and Leptocardii, prepared for the Smithsonian Institution." In that opuscule, the living fin-bearing branchiferous vertebrates were divided into 3 classes, 21 orders, and 244 families. The sequence was based upon a consideration of their morphology, really commencing with the most generalized or primitive types and ending with the most specialized. The author's views as to their approximate relations were given in the introduction to the memoir (pages xix–xlii), in which the Leptocardians were regarded as the lowest of the vertebrates and the Pediculates, in some respects, the most specialized. Nevertheless, in obedience to the wish of Prof. Baird, at that time Assistant Secretary of the Smithsonian Institution, the sequence was reversed in the list of families, and the series commenced with the order Plectognathi and terminated with the Leptocardii. At that time people generally had not been accustomed to see the vertebrates arranged with the lowest first, and it was with the desire of conforming as nearly as possible to prevailing usage that the generally adopted sequence was preserved.

Since the publication of the arrangement, numerous observers have published the results of their studies in the various departments of morphology and taxonomy of the branchiferous classes. Many new species and several entirely new types have been discovered and described, and the light that has been thrown upon the structure of various forms, living and extinct, renders it desirable that a new census of the several classes should be taken. The present list of families and subfamilies is the outcome of such a review.

As already indicated, in the "Arrangement of the Families of Fishes" of 1872 the names of 244 families appeared. In the introduction it was remarked that—

> The families have been much multiplied and, it may be urged, unduly so, and such may really be the case, but as analysis should precede synthesis, and as many of the more comprehensive families have either not received diagnoses common to and at the same time peculiar to all their constituents, or, in case of applicable diagnoses, the characters are of suspicious value, it has been deemed best to isolate the groups as families and allow them to stand on their own merits. Several of the families admitted (*e. g., Gadiform, Labyrinthiciform, Scombriform, Perciform, Siluriform*) are, however, of very dubious value, and are only provisionally adopted and kept in prominence to attract future examination.

Subsequent studies, instead of invalidating the families that were thus regarded as being of suspicious value, have rather confirmed them (or at least most of them), and all of the series just named have been retained in the present list. The latest authors that have published on any of those groups are Dr. and Mrs. Carl Eigenmann, who have studied the long neglected rich collections of Nematognath or siluriform fishes made by the late Prof. Agassiz and associates in South America. All of the families named in the arrangement have been adopted as a consequence of the profound studies of Dr. and Mrs. Eigenmann. The author, therefore, has little hesitation in retaining all of the families named in the arrangement and has even added a number of others, some of which have been dissevered from previously recognized groups, while others are the result of discoveries made since 1872. Several other of the most independent ichthyologists of the United States, and who are well entitled to the most attentive consideration on account of the

wide range and thoroughness of their researches, have likewise adopted most of the families proposed by the author when they chanced to treat of forms embraced in any of them. Such are President David S. Jordan and Prof. Charles H. Gilbert, of the University of California, Dr. G. Brown Goode, Director of the United States National Museum, and Dr. Tarleton Bean, the Curator of Fishes of the same museum. Prof. E. D. Cope, while often differing, has also accommodated his views in many instances to those enunciated by myself. When so many independent and eminent authorities more or less agree, there is good reason to believe that the views in which they concur can not be very far wide of the truth, however much they may deviate from those prevalent in other parts of the world.

For while there is essential accord among American ichthyologists as to the limits of families, the divergence among them being slight, there is a great divergence in that respect from most European ichthyologists. It may be well, then, to sustain the current American usage in the limitation of the families of fishes by reference to the treatment of well-studied groups of other classes by the most competent European authorities.

The illustrious Huxley, in his memoirs and well-known volume on the crayfishes and their relations, has exemplified the extent to which family differentiation should be carried, in his work. An equally celebrated and profound German naturalist, Prof. Häckel, in the various classes which he has studied, has adopted similar principles. The numerous ornithological authors, forming so large a contingent of the army of science, have even carried the discrimination of families to a much greater extent.

It is scarcely possible that anyone who should carefully study the morphology and characteristics generally of the families of passerine birds, for example, and who should likewise survey the morphology and characteristics of the families of fishes, could deny that there is scarcely one (if any) of the families of fishes based upon characters so trivial as those which have served for the differentiation of the great majority of those belonging to the great group of Passeres. If, therefore, the general zoölogist has the slightest desire to be consistent, he must either reject most of the families of birds and recombine them or apply a far stricter analysis to the families of fishes than is generally used in Europe. But, indeed, we have not to go outside the classes of fishes to notice inconsistencies. Anyone who reviews the characteristics on which the families of Percoidean and Scombroidean fishes have been distinguished must recognize that the distinctions which have been employed to separate them are of far less value and significance than the characters which differentiate various constituents or constituents in the sets of families as recognized by ichthyologists of the old school.

The author insists, as in previous publications, on the entirely provisional nature of the present arrangement. Changes—grave changes—must necessarily be made in the system when the species shall be studied in a more scientific way than has been generally done heretofore. Many families are entirely unknown in an anatomical point of view, and until their structure has been investigated and carefully compared with that of others, their systematic relations must remain doubtful. No scientific investigator should fear to change his opinion. An obstinate persistence in ancient views because they have been once adopted has been too long detrimental to the interests of systematic ichthyology, and such obstinacy has retarded the general progress of science for twenty to thirty years. While the aspect of every other branch of vertebrate zoölogy has entirely changed within that period, ichthyology, the most complex and the least advanced of all, might appear to the casual observer to have had a more certain basis than any, inasmuch as the text-books of a past generation have essentially the same system as the latest. Either almost omniscience and prescience were the attributes of the guides of the past who keep to the same path in the present, or obstinacy and blindness to an extraordinary degree have been manifested. To a great extent ichthyology has been limited to descriptions of species or habits, and taxonomic principles have been quite neglected. One author even, treating of the fish fauna of Great Britain, had appreciated a few of the faults of the system he adopted, and yet seriously gave as a reason for adopting it that "specimens are arranged in the national collection in accordance with it."* If such reasons were generally regarded as sufficient we might well despair of any rapid progress of

*Day's Fishes of Great Britain and Ireland, vol. I, p. xxix, 1884.

ichthyology, but let us hope that few could reason so and that museums may not become obstacles to the advancement of science, but be used for its furtherance only.

The National Museum of the United States may be the first in which provision is made for the thorough study of systematic ichthyology. The policy of having a skeleton of every species has been recognized by its enlightened director, Dr. Goode, and we may hope that before many years have passed a collection may be formed which will be worthy of a national museum and may serve to put ichthyology on a sound basis.

Meanwhile ichthyology is still a crude and inchoate science. The present list has been prepared as a check-list and adjuvant to the use of the collection. Many families have been allocated in their positions simply because they have been placed there before and because equal doubts would be involved in placing them elsewhere. In many cases, it is certain that the general conceptions of their relations (if so positive a term may be applied to what are vague reiterations of past utterances) are baseless, but the indications furnished by the exterior is insufficient to justify positive conclusions. Until the anatomy or at least the osteology of every family and subfamily is known, much doubt must remain as to the proper allocation of such groups.

In order to furnish clews to the literature, the names of the proposers and modifiers of family terms are appended, and the dates will enable the student to obtain the desired result by use of the recognized channels of information. The names of authors inclosed within parentheses are of those who have given the name in more or less different forms or with different ranges of characters; those in open space are of such as have given the forms adopted and also essentially the same limits.

In the family names derived from compounds with *πους*, the shorter termination—*pidæ* is adopted rather than—*podidæ*. (Compare the alternative or poetical forms *πολύπους*, gen. *πολύπου*, *θηλύπους*, gen. *θηλύπου*, etc.) Thus *Lepidopidæ* is used instead of *Lepidopodidæ*.

In names derived from compounds with *στωμα* and similar words the termination—*idæ* is also employed, as *Ginglymostomidæ*. As this is contrary to almost universal usage among naturalists, I can not do better than cite, in this connection, the words of the scholarly Hermannsen.*

Class MYELOZOA (Is. Geoffr. St. Hil., Bonaparte, 1856), or LEPTOCARDIANS.

Order AMPHIOXI (Bon., 1846).

1. Branchiostomidæ Bon., 1846.

Class MARSIPOBRANCHII or MYZONTS.

Order HYPEROTRETA (Müller, 1844).

2. Heptatremidæ Gill, 1892=Bdellostomidæ Gill, 1872.
3. Myxinidæ (Raf., 1810) Gill, 1872.

Order HYPEROARTIA (Müller, 1844).

4. Mordacidæ Gill, 1892.
5. Petromyzontidæ Risso, 1826.
   - *a. Petromyzontinæ* (Bon., 1832) Gill, 1892.
   - *b. Geotrinæ* Gill, 1892.

Class SELACHIANS.

Order OPISTHARTHRI (Gill, 1882).

6. Chlamydoselachidæ Garman, 1884.
7. Hexanchidæ Gill, 1885=Notidanidæ (M. H.).

Order PROSARTHRI.

8. Heterodontidæ Gill, (1862) 1872=Cestraciontidæ (Agass., 1883) Owen, 1846.

Order TECTOSPONDYLI.

9. Echinorhinidæ Gill (1862), 1872.
10. Oxynotidæ Gill (1862), 1872.
11. Squalidæ (Bon., 1832) Gill, 1888=Spinacidæ.
12. Dalatiidæ Gill, 1892=Scymnidæ (Müller and Henle, 1845).
    - *a. Somniosinæ* Gill, 1888.
    - *b. Dalatiinæ* Gill, 1892=*Scymninæ* (Bon., 1837), Gill.

* Vocabula composita Græcæ originis, quorum terminalis radix generis neutralis, in *α* exiens, genitivo *ατος* flectitur, *nonnisi adjective* sensu adhibentur. Hinc si neutralis numero plurali obveniunt, ut Adelodermata, Cricostoma, terminentur genitivo *orum;* sin autem singulari numero, ut Amphidesma, Cyclostoma, feminini erunt generis, et declinabimus „Cyclostomæ."—Documento sint veterum nomina *ὀστρακόδερμα, τρίστομος, ἄδερμος.*

"Omni vel specie rectæ rationis, qui *Pleurotomam* similiaque vocabula neutralis generis habent. Conferatur *πγρίτομος*."—Hermannsen, Indicis Generum Malacozoorum Primordia, vol. I, 1846, p. xiii.

Class SELACHIANS—Continued.

Order ASTEROSPONDYLI.

13. Galeidæ (Rich., 1848), Gill, 1892=Galeorhinidæ Gill (1862), 1872.
    a. Galeorhininæ Gill, 1862.
    b. Galeinæ Gill, 1892, or *Mustelinæ* Bon.
14. Scylliorhinidæ Gill (1862), 1872, or Scyllidæ (Müller and Henle, 1877), Rich.
    a. Scylliorhininæ Gill, 1862.
    b. Parascylliinæ Gill, 1862.
    c. Hemiscylliinæ Gill, 1862.
    d. Pseudotriacinæ Gill, 1892.
15. Ginglymostomidæ Gill (1862), 1892.
    a. Ginglymostominæ Gill, 1862.
    b. Stegostominæ Gill, 1862.
16. Crossorhinidæ Gill (1862), 1872.
17. Alopiidæ Gill, 1885.
18. Carcharidæ Gill, 1892=Odontaspididæ (Müller and Henle, 1837) Gill, 1862.
19. Isuridæ Gill, 1892.
    a. Carcharodontinæ Gill, 1892.
    b. Isurinæ (Gray, 1851) Gill, 1892.
20. Cetorhinidæ Gill, 1872.
21. Rhinodontidæ (Müller and Henle) Richardson, 1856.
22. Pristiophoridæ (Bleeker, 1859) Günther, 1870.

Suborder RHINÆ.

23. Squatinidæ (Müller and Henle, 1837), Gray, 1851.

Order HYPOTREMI.

Suborder SARCURA.

(**Pristoidea.**)

24. Pristidæ (M. and H., 1837) Bon., 1846.

(**Raioidea.**)

25. Rhamphobatidæ Gill (1872).
26. Rhinobatidæ (Müller and Henle, 1841), Rich., 1856.
27. Raiidæ (Bonaparte, 1831), Rich., 1856.

(**Torpedinoidea.**)

28. Torpedinidæ (M. and H., 1841), Rich., 1856.
    a. Torpedininæ (Bon., 1837), Gill, 1862.
    b. Narcininæ Gill, 1862.
    c. Hypninæ Gill, 1862.

Suborder MASTICURA.

(**Dasybatoidea.**)

29. Dasybatidæ Gill (1892), or Trygonidæ (M. and H.) Rich., 1856.
    a. Dasybatinæ Gill, 1892, or *Trygoninæ* (Bon., 1837).
    b. Paratrygoninæ Gill, 1892.
    c. Pteroplatcinæ Gill, 1892.

Aetobatoidea.

30. Aetobatidæ Jordan, 1888=Myliobatidæ (M. and H., 1837).
    a. Aetobatinæ Gill, 1892, *Myliobatinæ* (Bon., 1837) Agass.
    b. Stoasodontinæ Gill, 1892=*Etobatinæ* Agass.
31. Mobulidæ Gill, 1892=Cephalopteridæ (M. and H., 1837).

Class SELACHIANS—Continued.

Subclass HOLOCEPHALI.

Order HOLOCEPHALI.

32. Chimæridæ Bonaparte, 1831.
    a. Chimærinæ Bon., 1831.
    b. Harriottiinæ Gill, 1892.

Class TELEOSTOMES or TRUE FISHES.

Subclass DIPNOI Müller, 1845.

Order Sirenoidei Müller, 1843.

Suborder MONOPNEUMONA.

33. Ceratodontidæ Gill, 1872.

Suborder DIPLOPNEUMONA.

34. Lepidosirenidæ Bonaparte, 1841.
    a *Lepidosirenin*æ (Bonaparte, 1841) Gill, 1876.
    b *Protopterinæ* Gill, 1876.

Subclass BRACHIOGANOIDEA.

Order CROSSOPTERYGII.

35. Polypteridæ Bon., 1846.
    a *Polypterinæ* (Bon., 1837) Gill, 1892.
    b *Calamoichthyinæ* Gill, 1892.

Subclass CHONDROGANOIDEA.

Order CHONDROSTEI.

36. Acipenseridæ Bon., 1831.
    a *Scaphirhynchopinæ* Gill, 1892.
    b *Acipenserinæ* (Bon., 1837).

Order SELACHOSTOMI.

37. Polyodontidæ Bon., 1837.

Subclass HYOGANOIDEA.

Order RHOMBOGANOIDEA.

38. Lepidosteidæ Bon., 1837.

Order CYCLOGANOIDEA.

39. Amiidæ Bon., 1837.

Subclass TELEOSTEI.

Order MALACOPTERYGII.

(**Osteoglossoidea.**)

40. Osteoglossidæ (Bon., 1846).
41. Arapaimidæ (Bleeker, 1859).
42. Heterotidiidæ (Cope, 1871).
43. Pantodontidæ (Peters, 1876), Günther, 1880.

(**Hyodontoidea.**)

44. Hyodontidæ (Val., 1846), Günther, 1868.

(**Albuloidea.**)

45. Albulidæ (Bleeker, 1859), Gill, 1872.

Class TELEOSTOMES, etc.—Continued.

Subclass TELEOSTEI—Continued.

Order MALACOPTERYGII—Continued.

(Elopoidea).

46. Elopidæ (Val., 1856), Richardson, 1856.
    a. *Elopinæ* (Bon., 1846), Jordan and Gilbert, 1882.
    b. *Megalopinæ* Jordan and Gilbert, 1882.

(Clupeoidea).

47. Chirocentridæ (Bleeker, 1859), Günther, 1868.
48. Chaneidæ Gill, (1872) Lutodeiroidei Bleeker, 1859.
49. Dussumieridæ Gill, 1872.
50. Clupeidæ (Bon., 1831), Gill, 1872.
51. Dorosomidæ Gill, 1872.
52. Stolephoridæ Gill, 1881=Engraulididæ Gill, 1872.
53. Alepocephalidæ (Val., 1846) Richardson, 1856.
54. Pterothrissidæ Gill, 1892=Bathythrissidæ Günther, 1877.

(Salmonoidea).

55. Argentinidæ Gill, 1881.
    a. *Argentininæ* (Bon., 1846), Gill, 1884.
    b. *Retropinninæ* Gill, 1892.
    c. *Plecoglossinæ* Gill, 1867.
56. Microstomidæ Gill (1861) 1872.
    a. *Microstominæ* Gill, 1861.
    b. *Bathylaginæ* Gill, 1892.
57. Thymallidæ Gill, 1884.
58. Salmonidæ (Raf., 1815), Gill, 1884.
    a. *Salmoninæ* (Bon., 1831), Gill, 1892.
    b. *Coregoninæ* Gill, 1892.
59. Salangidæ Gill, 1872.

(Notopteroidea).

60. Notopteridæ (Bleeker, 1859), Günther, 1868.

(Gonorhynchoidea).

61. Gonorhynchidæ (Bleeker, 1859).

(Galaxioidea).

62. Galaxiidæ Richardson, 1856.
63. Haplochitonidæ Günther, 1868.

(Aulopoidea).

64. Aulopidæ Cope, 1871.

(Iniomi*).

65. Synodontidæ Gill, 1872.
66. Benthosauridæ Gill, 1892.
67. Bathypteroidæ Gill, 1888.
68. Myctophidæ Gill, 1892=Scopelidæ (Müller, 1843), Rich., 1848.
    a. *Scopelinæ* (Bon., 1846), Gill, 1892.
    b. *Odontostominæ* Gill, 1892.

Class TELEOSTOMES, etc.—Continued.

Subclass TELEOSTEI—Continued.

Order MALACOPTERYGII—Continued.

(Iniomi)—Continued.

69. Macrolocidæ Gill, 1884.
70. Chauliodontidæ Bon., 1846.
71. Gonostomidæ Gill, 1892.
72. Astronesthidæ Gill, 1892.
73. Stomiatidæ Günther, 1864.
74. Ipnopidæ Gill, 1883.
75. Malacosteidæ Gill, 1892.
76. Idiacanthidæ Gill, 1892.

(Paralepidoidea).

77. Alepisauridæ Bon., 1846.
78. Paralepididæ Gill, 1872.

(Sternoptychoidea).

79. Sternoptychidæ (Dum., 1806), Gill, 1884.
    a. *Sternoptychinæ* (Rap., 1815), Gill 1884.
    b. *Argyropelecinæ* Gill, 1884.
    c. *Polyipninæ* Gill, 1892.

(Incertæ sedis).

80. Rondeletiidæ Goode & Bean, 1892.
81. Cetomimidæ Goode & Bean, 1892.

Order PLECTOSPONDYLI.

Suborder HETEROGNATHI.

82. Characidæ Gill, 1892=Characinidæ (Müller and Troschel).
    a. *Tetragonopterinæ* (Gill, 1858).
    b. *Hydrocyoninæ* (Bon., 1837; Günther, 1864.
    c. *Distichodontinæ* (Günther, 1864).
    d. *Ichthyoborinæ* (Gthr., 1864).
    e. *Crenuchinæ* (Gthr., 1864).
    f. *Xenocharacinæ* (Gthr., 1864).
    g. *Serrasalmoninæ* (Gthr., 1864).
    h. *Characinæ* (Gill, 1891)=*Anostominæ* (Gthr., 1864)=*Myletidini* (Bon., 1837).
    i. *Citharininæ* (Gthr., 1864).
    j. *Curimatinæ* (Bleeker, 1859; Günther, 1864).
    k. *Stevardiinæ* Gill, 1859.
83. Erythrinidæ (Val., 1846; Bleeker, 1859).
    a. *Pyrrhulininæ* Gill, 1891.
    b. *Lebiasininæ* Gill, 1891.
    c. *Erythrininæ* Gill, 1858.

Suborder EVENTOGNATHI

84. Catastomidæ Gill, 1861.
    a. *Ichthyobinæ* Jordan (1888)=*Rubalichthyinæ* Gill, 1861.
    b. *Cycleptinæ* Gill, 1861.
    c. *Catostominæ* Gill, 1861.

* The families comprised under the designation of *Iniomi* do not appear to form a homogeneous group, and may be hereafter distributed under several superfamilies or even widely dispersed and otherwise associated, but the data are not at present in hand to undertake the requisite examination.

Class TELEOSTOMES, etc.—Continued.

Subclass TELEOSTEI—Continued.

Order PLECTOSPONDYLI—Continued.

Suborder EVENTOGNATHI—Continued.

85. CYPRINIDÆ (Bon., 1837) Gill, 1861.
    a. *Cyprininæ* (Bon., 1831).
    b. *Rohteichthyinæ* (Günther, 1868).
    c. *Leptobarbinæ* (Günther, 1868).
    d. *Danioninæ* (Günther, 1868).
    e. *Semiplotinæ* (Günther, 1868).
    f. *Xenocypridinæ* (Günther, 1868).
    g. *Leuciscinæ* (Bon., 1837).
    h. *Rhodeinæ* (Günther, 1868).
    i. *Hypophthalmichthyinæ* (Günther, 1868).
    j. *Abramidinæ* (Günther, 1868).
    k. *Medinæ* Gill, 1892 = *Plagopterinæ* Jordan and Gilbert, 1882.
    l. *Eroglossinæ* Jordan and Gilbert, 1882.
    m. *Campostominæ* Jordan and Gilbert, 1882.
86. HOMALOPTERIDÆ Gill, 1861.
87. COBITIDÆ (Swainson, 1839).
88. KNERIIDÆ Günther, 1868.

Suborder GYMNONOTI.

89. GYMNOTIDÆ (Bon., 1846) Gill = STERNOPYGIDÆ Cope, 1871.
    a. *Gymnotinæ* (Bon., 1831) Gill, 1892 = *Carapini* Bon., 1850.
    b. *Sternarchinæ* Gill, 1892.
90. ELECTROPHORIDÆ Gill, 1872 = GYMNOTIDÆ Cope, 1871.

Order NEMATOGNATHI.

91. DIPLOMYSTIDÆ Eigenmann, 1891.
92. SILURIDÆ (Cuv., 1817), Gill, 1872.
    a. *Batrachocephalinæ* Gill, 1892.
    b. *Tachisurinæ* C. and R. Eigenmann, 1891 = *Ariinæ* (Günther, 1864).
    c. *Bagariinæ* (Günther, 1864).
    d. *Rhinoglanidinæ* (Günther, 1864).
    e. *Pimelodinæ* (Bleeker, 1858).
    f. *Bagrinæ* (Bleeker, 1858; Günther, 1864).
    g. *Ictalurinæ* (Gill, 1861) Jordan.
    h. *Olyrinæ* Gill, 1892.
    i. *Erethistinæ* Gill, 1892.
    j. *Silurinæ* (Bon. 1831), Gill, 1892.
    k. *Ailiinæ* (Bleeker, 1858), Gill, 1892.
    l. *Auchenipterinæ* Gill, 1892.
    m. *Doradinæ* (Gthr., 1864).
    n. *Ageneiosinæ* (Bleeker 1858), Gill, 1892.
93. MALAPTERURIDÆ Gill, 1892.
94. CHACIDÆ Gill, 1872.
95. PLOTOSIDÆ Gill, 1872.
96. CLARIDÆ Gill 1872.
    a. *Clariinæ* (Bon., 1846).
    b. *Heterobranchinæ* Gill, 1892.
97. CALLICHTHYIDÆ Gill, 1872.
98. ARGHIDÆ Gill, 1872; Eigenmann, 1888.
99. SISORIDÆ Gill, 1872.
100. LORICARIIDÆ Bon. 1837.
    a. *Loricariinæ* (Bon. 1831).
    b. *Hypostominæ* (Bleeker, 1879).

Class TELEOSTOMES, etc.—Continued.

Subclass TELEOSTEI—Continued.

Order NEMATOGNATHI—Continued.

101. ASPREDINIDÆ (Bleeker, 1859).
    a. *Aspredininæ* (Bleeker, 1862), Eigenmann, 1891.
    b. *Bunocephalinæ* (Bleeker, 1862), Eigenmann, 1891.
102. HYPOPHTHALMIDÆ Cope, 1871.
103. PYGIDIIDÆ C. and R. Eigenmann (1888)=TRICHOMYCTERIDÆ Gill, 1872.
    a. *Cetopsinæ* (Bleeker 1858), C. and R. Eigenmann, 1858.
    b. *Pygidiinæ* C. and R. Eigenmann (1888)=*Trichomycterinæ* (Bleeker, 1858).
    c. *Nematogenyinæ* (Günther, 1864)
    d. *Stegophilinæ* (Günther, 1864).

Order SCYPHOPHORI.

104. MORMYRIDÆ Bon., 1837.
    a. *Mormyrinæ* (Bon., 1831), Gill, 1859.
    b. *Petrocephalinæ* Gill, 1862.
105. GYMNARCHIDÆ (Bleeker, 1859) Gthr., 1864.

Order SYMBRACHIA.

(Symbranchoidea).

106. SYMBRACHIDDÆ (Swainson 1839), Gill, 1872.
107. MONOPTERIDÆ Gill, 1872.

(Amphipnoidea.)

108. AMPHIPNOIDÆ Gill, 1872.

(Chilobranchoidea.)

109. CHILOBRANCHIDÆ Gill, 1872.

Order CARENCHELI.

110. DERICHTHYIDÆ Gill, 1884.

Order APODES.

Suborder ENCHELYCEPHALI.

(Anguilloidea.)

111. LEPTOCEPHALIDÆ (Kaup., 1856), JORDAN = CONGRIDÆ (Kaup., 1856.)
112. ANGUILLIDÆ (Raf., 1810), Kaup., 1856.
113. SIMENCHELYIDÆ Gill, 1879.
114. ILYOPHIDÆ Gilbert (1891).
115. SYNAPHOBRANCHIDÆ Johnson (1862).
116. HETEROCONGRIDÆ Jordan and Davis (1891).
117. NETTASTOMIDÆ Jordan & Davis, 1891.

(Ophichthyoidea.)

118. MURÆNESOCIDÆ (Cope, 1872), Gill, 1890.
119. OPHICHTHYIDÆ Gill (1885) = OPHISURIDÆ (Risso, 1826), Kaup., 1856.
    a. Ophichthyinæ Gill, 1892.
    b. Sphagebranchinæ Gill, 1892.
    c. Myrinæ Kaup, 1856.

(Incertæ sedis.)

120. DYSOMMIDÆ, Gill, 1892.

Class TELEOSTOMES, etc.—Continued.

Subclass TELEOSTEI—Continued.

Order APODES—Continued.

Suborder ENCHELYCEPHALI—Continued.

(Nemichthyoidea.)

121. NEMICHTHYIDÆ Gill, 1872.
    a. Spinirostrinæ Gill, 1892.
    b. Nemichthyinæ (Gthr., 1870).
    c. Gavialicipitinæ Gill, 1892.

Suborder COLOCEPHALI.

122. MURÆNIDÆ (Risso., 1826), Cope, 1871, 1872.
123. MYROCONGRIDÆ Gill, 1892.
124. MORINGUIDÆ Gill, 1885 = RATABURIDÆ Cope 1872.

Order LYOMERI, Gill and Ryder, 1883.

125. SACCOPHARYNGIDÆ (Bleeker, 1859), Gill, 1872.
126. EURYPHARYNGIDÆ Gill, 1883.

Order XENOMI, Gill.

127. DALLIIDÆ Gill, 1885.

Order OPISTHOMI (Cope, 1870), Gill. 1872.

128. MASTACEMBELIDÆ (Gthr., 1861).

Order HETEROMI.

129. NOTACANTHIDÆ (Raf., 1810), Gthr., 1861.
130. LIPOGENYIDÆ, Gill, 1892.

Order TELEOCEPHALI.

Suborder HAPLOMI.

131. ESOCIDÆ (Cuv., 1817; Bon., 1831).
132. UMBRIDÆ (Val.), Gthr., 1866.
133. POECILIIDÆ, Bon., 1837 = CYPRINODONTIDÆ (Ag., 1834).
    a. Cyprinodontinæ (Gill, 1861), J. and G., 1882.
    b. Fundulinæ (Gthr., 1866) = *Hydrargyrinæ* (Gill, 1861).
    c. Orestiinæ Gill, 1892.
    d. Jenynsiinæ (Gthr., 1866).
    e. Anablepinæ (Bon., 1837).
    f. Gambusiinæ, Gill, 1892.
    g. Poeciliinæ (Bon., 1837) J. and G., 1882.
134. AMBLYOPSIDÆ Bon., 1846.

Suborder SYNENTOGNATHI.

135. EXOCŒTIDÆ (Risso, 1826; Bon., 1846) Gill, 1872 = SCOMBERESOCIDÆ (Müller, 1842) Rich.
    a. *Exocœtinæ* (Bon., 1837) Gill, 1861.
    b. *Hemirhamphinæ* Gill, 1861.
    c. *Scomberesocinæ* Gill, 1859.
136. BELONIDÆ Gill, 1872.

Class TELEOSTOMES, etc.—Continued.

Subclass TELEOSTEI—Continued.

Order TELEOCEPHALI—Continued.

Suborder UNCERTAIN.

(Percopsoidea.)

137. PERCOPSIDÆ (Agass. 1846) Günther, 1868.

(Aphrododeroidea.)

138. Aphredederidæ Bon., 1846.

Suborder PERCESOCES.

139. SPHYRÆNIDÆ (Raf., 1815) Bon., 1831.
140. ATHERINIDÆ (Risso, 1836) Bon., 1837 (incl. Pseudomugilidæ).
141. MUGILIDÆ (Cuv., 1829) Bon., 1831.

Suborder ACANTHOPTERYGII.

(Berycoidea.)

142. STEPHANOBERYCIDÆ Gill, 1884.
143. BERYCIDÆ Lowe, 1884.
    a. *Berycinæ* Gill, 1862.
    b. *Melamphainæ* Gill, 1892.
    c. *Anoplogastrinæ* Gill, 1892.
144. TRACHICHTHYIDÆ (Bkr., 1859).
145. MONOCENTRIDÆ Gill, 1859.
146. HOLOCENTRIDÆ (Rich., 1846) Gill, 1885.
147. ANOMALOPIDÆ Gill, 1885.

(Scombroidea.)*

148. ELACATIDÆ Gill (1862), 1888.
149. POMATOMIDÆ Gill, 1865.
150. DREPANIDÆ Gill, 1872.
151. CARANGIDÆ (Bleeker, 1859) Gill, 1872, 1883.
    a. *Chloroscombrinæ* Gill, 1862.
    b. *Seriolinæ* Gill (1861), 1883.
    c. *Caranginæ* (Raf., 1815) Gill, 1862.
    d. *Vomerinæ* (Bon., 1838) Gill, 1862.
    e. *Trachynotinæ* Gill, 1862.
    f. *Scombroidinæ* J. and G., 1862.
    g. *Paropsinæ* Gill, 1883.
152. NEMATISTIIDÆ Gill, 1862.
153. SCOMBRIDÆ (Raf., 1815) Bon., 1831.
    a. *Sardinæ* Gill, 1888 = *Oreyninæ* (Gill, 1861).
    b. *Scombrinæ* (Bon., 1831) Gill, 1861.
    c. *Gempylinæ* Gill, 1862.
    d. *Thyrsitinæ* Gill, 1862.
154. LEPIDOPIDÆ Gill, 1885.
    a. *Aphanopinæ* Gill, 1892.
    b. *Lepidopinæ* Gill, 1863.
155. TRICHIURIDÆ (Raf., 1810) Gill, 1885.
156. HISTIOPHORIDÆ (Raf., 1810) Gill, 1883.
157. XIPHIIDÆ (Raf. 1810) Gill, 1883.
158. CORYPHÆNIDÆ (Lowe, 1839).
159. BRAMIDÆ (Lowe, 1836).

*The *Scombroidea* as still retained do not constitute a natural group and will undoubtedly be hereafter dispersed and otherwise associated, but the task can only be done with good anatomical material, and as naturalists are accustomed to find the families in more or less close juxtaposition convenience dictates the continuance of such collocation for the present. It is certain, however, that their dispersion on account of differences in the relative proportions of the first and second dorsal fins or the development of an ensiform weapon outrages all natural affinities.

Class TELEOSTOMES, ETC.—Continued.

Subclass TELEOSTEI—Continued.

Order TELEOCEPHALI—Continued.

Suborder ACANTHOPTERYGII—Continued.

(**Scombroidea**)—Continued.

160. Pteracladidæ, Gill, 1872.
161. Stromateidæ (Raf., 1810) Gill, 1862.
    a. *Centrolophinæ* Gill, 1861, 1884.
    b. *Stromateinæ* (Raf., 2815), Gill, 1861, 1884.
    c. *Icosteinæ* J. and G., 1882.
    d. *Icichthyinæ*, J. and G., 1882.
162. Acrotidæ Gill, 1892.
163. Grammicolepididæ (Poey, 1873).
164. Nomeidæ Gthr., 1861.
    a. *Nomeinæ* (Gthr., 1860).
    b. *Gasteroschismininæ*, Gill, 1892.
165. Pempheridide Gill, 1862.
166. Luvaridæ Gill, 1885.
167. Lampridide Gill, 1862.
168. Menidæ Gill, 1885.
169. Liognathidæ Gill, 1892 = Equulidæ (Bleeker, 1859) Gill, 1872.
170. Zeidæ (Swains., 1839).
    a. *Zeinæ* (Bon., 1831) = *Cyttinæ*, Gthr., 1860.
171. Caproidæ (Lowe, 1844).

(**Tetragonuroidea.**)

172. Tetragonuridæ (Risso., 1826), Bon., 1837.

(**Percoidea.**)

173. Centrarchidæ Gill, 1864.
    a. *Centrarchinæ* Gill, 1864.
    b. *Lepominæ* Gill, 1864.
    c. *Micropterinæ* Gill, 1864.
174. Elassomidæ (J. and G., 1882).
175. Percidæ (Cuv., 1817, Bon., 1831).
    a. *Gymnocephalinæ* Gill, 1891=*Acerininæ* (Blkr.).
    b. *Percinæ* (Bon., 1831).
    c. *Etheostominæ* (Agass., 1848) J. and G.
176. Chilodipteridæ (Blkr., 1859) Gill, 1872=Apogonidæ.
    a. *Enoplosinæ* Gill, 1891.
    b. *Chilodipterinæ* Gill.
177. Acropomidæ Gill, 1891.
178. Scombropidæ Gill, 1891.
179. Serranidæ (Rich., 1848) Gill, 1872.
    a. *Serraninæ* (Swains., 1839).
    b. *Gramimistinæ* Gill, 1892.
    c. *Polypriontinæ* (Blkr., 1876).
    d. *Myriodontinæ* (Blkr., 1876).
    e. *Diplopriontinæ* (Blkr., 1876).
    f. *Dischistiinæ* Gill, 1891.
    g. *Latinæ* Gill, 1891=*Labracinæ*.
180. Lobotidæ Gill (1862), 1883.
181. Rhypticidæ Gill, 1885.
182. Kyphosidæ = Pimelepteridæ (Blkr., 1859) Gill, 1862.
    a. *Kyphosinæ* = *Pimelepterinæ* Gill, 1862.
    b. *Scorpidinæ* (Gthr., 1860) Gill, 1862.
    c. *Girellinæ* Gill, 1862.
183. Theraponidæ (Rich., 1856).

Class TELEOSTOMES, ETC.—Continued.

Subclass TELEOSTEI—Continued.

Order TELEOCEPHALI—Continued.

Suborder ACANTHOPTERYGII—Continued.

(**Percoidea**)—Continued.

184. Hæmulonidæ (Rich., 1848)=Pristipomidæ (Gthr., 1859.
    a. *Hæmulininæ* Gill, 1892= *Pristipominæ*, Gill, 1873.
    b. *Xenichthyinæ* Gill, 1863.
185. Lutjanidæ Gill, 1884.
    a. *Hoplopagrinæ* Gill, 1862.
    b. *Lutjaninæ* Gill, 1862, 1884.
    c. *Etelinæ* Gill, 1888=*Platyinini* Poey, 1868.
    d. *Denticinæ* (Blkr., 1876).
186. Apharidæ (Blkr., 1876).
187. Sparidæ (Bon., 1831).
    a. *Boridiinæ* (Blkr., 1876).
    b. *Sparinæ* (Bon., 1831).
188. Gerridæ (Gill, 1861) Gthr., 1862.
189. Mænidæ (Cuv., 1829) Bon. 1831.
    a. *Mæninæ* (Bon., 1831).
    b. *Centracanthinæ* Gill, 1891.
190. Sciænidæ (Cuv., 1829) Lowe.
    a. *Otolithinæ* Gill, 1862.
    b. *Sciæninæ* (Bon., 1832) Gill., 1862.
    c. *Equitinæ* Gill., 1862.
    d. *Haplodinotinæ* (Gill., 1862) Gill., 1891.
    e. *Liostominæ* (Gill., 1862.
191. Centropomidæ (Poey, 1865) Gill., 1883.

(**Related to Percoidea.**)

192. Polycentridæ Gthr., 1861.
193. Nandidæ (Blkr., 1859) Gthr., 1861.
194. Hoplegnathidæ (Rich.)
195. Sillaginidæ (Rich., 1846) Gill., 1861.
196. Pentacerotidæ Gill, 1885.
    a. *Anoplinæ* Gill, 1891.
    b. *Pentacerotinæ* Gill, 1891.
    c. *Histiopterinæ* Gill, 1891.
197. Veliferidæ (Blkr., 1879) Gill, 1891.

(**Priacanthoidea.**)

198. Pricanthidæ Gill, 1872.

(**Mulliidea.**)

199. Mullidæ (C. and V. 1828) Bon., 1831.

(**Polymixioidea.**)

200. Polymixiidæ Gill (1862), 1872.

(**Toxotoidea.**)

201. Toxotidæ (Blkr., 1859) Gill, 1872.

(**Scatophagoidea.**)

202. Scatophagidæ Gill, 1883.

(**Chaetodontioidea.**)

203. Ephippidæ Gill (1862), 1883.
204. Chætodontidæ (Bon., 1831) Gill, 1872.
    a. *Chætodontinæ* (Raf., 1815, Bon., 1831).
    b. *Holacanthinæ* Gill, 1892.
205. Zanclidæ Gill, 1885.

Class TELEOSTOMES, ETC.—Continued.

Subclass TELEOSTEI—Continued.

Order TELEOCEPHALI—Continued.

Suborder ACANTHOPTERYGII—Continued.

(Tenthidoidea.)

206. Teuthididæ (Lat., 1825) Gill, 1873=Acanthuridæ (Blkr., 1859) Gill, 1872.
207. Siganidæ (Rich.,1836) Gill, 1884=Amphacanthidæ (Blkr., 1859) Gill, 1872.

(Anabantoidea.)

208. Osphromenidæ Cope, 1871.
  a. *Osphromeninæ*.
  b. *Polyacanthinæ*.
  c. *Bettinæ*.
209. Anabantidæ (Rich., 1836) Bon., 1837.
210. Helostomidæ Gill. 1872.
211. Luciocephalidæ Gthr., 1861.

(Ophiocephaloidea.)

212. Ophiocephalidæ (Bon., 1831) Blkr., 1859.

(Pomacentroidea.)

213. Pomacentridæ Girard, 1858.
214. Cichlidæ (Blkr., 1859) Gill. 1872=Chromidæ (Müller, 1839) Bon., 1846.

(Labroidea.)

215. Holconotidæ (Blkr., 1859) Gill, 1891=Embiotocidæ (Agass., 1853) Girard, 1858.
  a. *Holconotinæ* Gill, 1892 = *Embiotocinæ* Gill, 1862.
  b. *Hysterocarpinæ* Gill, 1862.
216. Labridæ (Cuv. 1817, Bon., 1831) Gill.
  a. *Labrinæ* (Bon., 1831) Gthr.
  b. *Chilioninæ* Gill, 1892.
  c. *Charopinæ* (Gthr., 1861) Gill, 1863.
  d. *Xyrichthyinæ* Gill, 1862.
  e. *Coridinæ* Gill, 1892=*Julidinæ* (Gthr., 1861).
  f. *Gomphosinæ* Gill, 1862.
  g. *Anampsinæ* Gill, 1892.
  h. *Cheilininæ* Gill, 1892.
  i. *Pseudolabrinæ* Gill, 1892.
  j. *Clepticinæ* Gill, 1862.
  k. *Pseudodacninæ* (Gthr., 1861).
217. Odacidæ Gill, 1885.
218. Siphonognathidæ (Gill, 1862).
219. Scaridæ (Raf., 1810).
  a. *Scarinæ* (Bon.).
  b. *Sparisominæ* Gill, 1892.

(Cirritoidea.)

220. Cirritidæ (Gray, 1846) Gill, 1862.
221. Aplodactylidæ Gill, 1892.
  a. *Latridinæ* Gill, 1862.
  b. *Aplodactylinæ* (Gthr., 1860) Gill, 1862.

Class TELEOSTOMES, ETC.—Continued.

Subclass TELEOSTEI—Continued.

Order TELEOCEPHALI—Continued.

Suborder ACANTHOPTERYGII—Continued.

(Scorpaenoidea.)

222. Caracanthidæ Gill (1885) 1889.
223. Hexagrammidæ Gill, 1889 — Cheridæ (Swains., 1839).
  a. *Oxylebiinæ* Gill, 1862.
  b. *Hexagramminæ* Gill, 1862.
  c. *Ophiodontinæ* Gill, 1892.
224. Anoplopomidæ Gill, 1863.
  a. *Erilepidinæ* Gill, 1892.
  b. *Anoplopominæ* (J. and G., 1882).
225. Scorpænidæ (Risso, 1826; Swains., 1839) Gill, 1889.
  a. *Scorpæninæ* (Bon., 1831) Gill.
  b. *Sebastinæ* (Kaup, 1873) Gill.
  c. *Apistinæ* (Kaup, 1873) Gill.
226. Synanceidæ (Adams, 1854) Gill.
  a. *Synancеiinæ* (Kaup, 1873).
  b. *Pelorinæ* Gill, 1891.

(Platycephaloidea.)

227. Platycephalidæ (Blkr., 1859).
228. Bembrasidæ Kaup, 1873.
229. Hoplichthyidæ Gill, 1889.

(Cottoidea.)

230. Cottidæ (Rich., 1836) Girard, 1858.
  a. *Cottinæ* (Bon., 1831) J. and G., 1882.
  b. *Blepsiinæ* (Swains., 1839).
  c. *Ascelichthyinæ* J. and G., 1882.
  d. *Synchirinæ* Bean, 1891.
  e. *Psychrolutinæ* (J. and G., 1882) Gill, 1888.
231. Hemitripteridæ Gill, 1872.

(Cyclopteroidea.)

232. Cyclopteridæ (Bon., 1831) Gill, 1872.
233. Liparididæ Gill, 1872.
  a. *Liparidinæ* Gill (1861), 1864.
  b. *Paraliparidinæ* Gill, 1891 = *Amitrinæ* J. and G. 1882.

(Rhamphocottoidea.)

234. Rhamphocottidæ Gill, 1889.

(Agonoidea.)

235. Agonidæ Swains., 1839.
  a. *Agoninæ* Gill.
  b. *Aspidophoroidinæ* J. and G.

(Comephoroidea.)

236. Comephoridæ Gthr., 1861.

Class TELEOSTOMES, ETC.—Continued.

Subclass TELEOSTEI—Continued.

Order **TELEOCEPHALI**—Continued.

Suborder ACANTHOPTERYGII—Continued.

(**Percophoidea.**)*

237. Pseudochromidæ (Müll. and Trosch., 1849) Bleeker, 1859.
   a. *Cichlopinæ* (Bleeker, 1875).
   b. *Plesiopinæ* (Bleeker, 1875).
   c. *Pseudoplesiopinæ* (Bleeker, 1875).
238. Malacanthidæ Günther, 1861.
   a. *Malacanthinæ* Gill, 1892.
   b. *Caulolatilinæ* Gill, 1892.
   c. *Latilinæ* Gill (1861), 1872.
239. Bathymasteridæ Jordan, 1885.
240. Percophidæ Adams, 1854.
   a. *Percophinæ* Gill, 1892.
   b. *Paxapercidinæ* Gill, 1892.
241. Notothenidæ Gill, 1861.
   a. *Nototheniinæ* Gill, 1861.
   b. *Eleginopinæ* Gill, 1892=*Elegininæ*, Gill, 1861.
242. Harpagiferidæ Gill, 1861.
243. Chænichthyidæ Gill (1861), 1872.
   a. *Chænichthyinæ* Gill, 1861.
   b. *Pagetodinæ* Gill, 1861.
244. Chiasmodontidæ Gill, 1882.
245. Opisthognathidæ Gill, 1872.
246. Bovichthyidæ Gill (1861), 1872.
247. Trichodontidæ Gill (1861), 1872.
248. Hemerocœtidæ Gill, 1892.

(**Trachinoidea.**)

249. Trachinidæ (Risso, 1826; Bon., 1837), Gill.

(**Uranoscopoidea.**)

250. Uranoscopidæ Gill, 1861.
251. Leptoscopidæ Gill (1862), 1872.
252. Dactyloscopidæ Gill, 1872.

(**Batrachoidea.**)

253. Batrachidæ Swains., 1839.

(**Gobioidea.**)

254. Oxudercidæ Gthr., 1861.
255. Gobiidæ (Cuv., 1817; Bon., 1831).
   a. *Eleotridinæ* Gill, 1861.
   b. *Gobiinæ* (Bon., 1831), Gill, 1862.
   c. *Gobiopinæ* Gill, 1859.
   d. *Oxymetoponinæ* Gill, 1894.
   e. *Sicydiinæ* Gill, 1860.
   f. *Periophthalminæ* Gill, 1892.
   g. *Amblyopinæ* (Gthr. 1861).
   h. *Trypauchenine* (Gthr. 1861).
   i. *Luciogobiinæ* Gill, 1860.

Class TELEOSTOMES, ETC.—Continued.

Subclass TELEOSTEI—Continued.

Order **TELEOCEPHALI**—Continued.

Suborder ACANTHOPTERYGII—Continued.

(**Callionymoidea.**)

256. Platypteridæ Gill, 1872.
257. Callionymidæ Bon., 1837.

(**Cepoloidea.**)

258. Cepolidæ Bon., 1831.

(**Gadopsoidea.**)

259. Gadopsidæ Gunther, 1862.

(**Blennioidea.**)

260. Clinidæ Gill, 1885.
261. Blennidæ (Raf., 1810; Bon., 1831), Gill, 1872.
262. Xiphasiidæ Gill, 1885=Nemophidæ Kaup., 1858.
   a. *Xiphasiinæ* Gill, 1864.
   b. *Plagiotreminæ* Gill (1865), 1892.
263. Cryptacanthodidæ Gill (1861), 1872.
264. Stichæidæ Gill.(1864), 1872.
265. Pholidide Gill, 1892=Xiphidiontidæ Gill (1864), 1872.
266. Acanthoclinidæ Gthr., 1861.
267. Chænopsidæ Gill, 1865.
268. Anarrhichadidæ Gill, 1865.
269. Cebidichthyidæ Gill (1864), 1872.
270. Ptilichthyidæ Gill, 1885.

(**Patæcoidea.**)

271. Patæcidæ Gill, 1872.
272. Congiopodidæ Gill, 1889=Agriopodidæ Kaup., 1873.
273. Gnathanacanthidæ Gill, 1892.

(**Zoarceoidea.**)

274. Zoarcidæ (Swainson, 1839) Jordan and Gilbert, 1882=Lycodidæ (Gunther, 1862) Gill, 1872.
   a. *Zoarcinæ* Jordan and Gilbert, 1882.
   b. *Lycodinæ* Gill, 1863.
   c. *Gymnelinæ* Gill, 1863.

(**Ammodytoidea.**)

275. Ammodytidæ Bon., 1846.

(**Ophidioidea.**)

276. Brotulidæ (Adams, 1854) Gill, 1884.
   a. *Brotulinæ* (Swainson, 1839) Gill, 1863.
   b. *Brosmophyeinæ* Gill, 1863.
   c. *Bythitinæ* Gill, 1863.
   d. *Sircembinæ* Gill, 1863.
277. Brotulophidæ Gill (1872).
278. Ophidiidæ (Raf., 1810) Gill, 1872.

*The Percophoidæ are undoubtedly a heterogeneous group and need a thorough revision. It is not probable that the *Latilinæ* are related to the *Malacanthidæ*, although the species of *Caulolatilus* are referred to the genus *Latilus* by Dr. Günther and his followers. *Bathymaster* is also apparently more nearly related to the *Blennioidea* than the *Percophoidea*.

Class TELEOSTOMES, ETC.—Continued.

Subclass TELEOSTEI—Continued.

Order **TELEOCEPHALI**—Continued.

Suborder ACANTHOPTERYGII—Continued.

(**Ophidioidea**)—Continued.

279. Fierasferidæ Gill, 1861, 1884.
280. Ateleopidæ (Kaup., 1858) Gthr., 1862.
281. Cerdalidæ Jordan, 1885.
282. Xenocephalidæ Gill, 1872, 1884.
283. Congrogadidæ Gill, 1872, 1884.

(**Lophotoidea**.)

284. Lophotidæ (Bikr., 1859) Gthr., 1861.

Suborder HYPOSTOMIDES.

285. Pegasidæ Kaup, 1853.

Suborder RHEGNOPTERI.

286. Polynemidæ (Cuv., 1828) Rich., 1846.

Suborder CRANIOMI.

(**Trigloidea**.)

287. Triglidæ (Risso., 1826; Bon., 1831) Gill, 1889.
288. Peristediontidæ Gill (1889) 1892.

(**Dactylopteroidea**.)

289. Dactylopteridæ Gill, 1885.

Suborder DISCOCEPHALI (Bleeker, 1859) Gill, 1883.

290. Echeneididæ (Raf., 1810) Bon., 1832.

Suborder TÆNIOSOMI.

291. Trachypteridæ (Swains., 1839) Gill, 1889.
292. Regalecidæ Gill (1885) 1889.

Suborder XENOPTERYGII.

293. Gobiesocidæ (Bikr., 1859) Gthr., 1861.

Suborder ANACANTHINI (Müller, 1846) Cope, 1870.

294. Gadidæ (Raf., 1810) Gill, 1872, 1884.
   a. *Gadinæ* (Bon., 1832) Gill, 1863.
   b. *Phycinæ* (Swains., 1839) Gill, 1863.
   c. *Lotinæ* (Bon., 1839) Gill, 1863.
   d. *Ominæ* Gill, 1888 = *Ciliatinæ* Gill, 1863.
295. Brosmidæ (Adams, 1854) Gill, 1892.
296. Merluciidæ (Adams, 1864) Gill, 1872.
297. Ranicipitidæ Gill, 1872, 1884.
298. Bregmacerotidæ Gill, 1872, 1884.
299. Macruridæ Bon., 1838.
300. Bathyonidæ Gthr., 1886.

Class TELEOSTOMES, ETC.—Continued.

Subclass TELEOSTEI—Continued.

Order **TELEOCEPHALI**—Continued.

Suborder HETEROSOMATA.

301. Pleuronectidæ (Raf., 1810) Bon. (1832), 1846.
   a. *Hippoglossinæ* Gill, 1861.
   b. *Psettinæ* (Bon., 1846) Gill, 1889 = *Rhombinæ* (Gill, 1861).
   c. *Samarinæ* Jordan and Goss, 1889.
   d. *Oncopterinæ* Jordan and Goss, 1889.
   e. *Pleuronectinæ* (Bon., 1833) Gill, 1861 = *Platessinæ* (Bon., 1846) Jordan and Goss, 1889.
302. Soleidæ Bon., 1846.
   a. *Solcinæ* (Bon., 1833, 1846).
   b. *Cynoglossinæ* Jordan and Goss, 1889 = *Plagusiinæ* (Bon., 1846).

Order **HEMIBRANCHII** Cope, 1870.

(**Gasterosteoidea**).

303. Gasterosteidæ Bon., 1840.
   a. *Apeltinæ* Gill, 1884.
   b. *Gasterosteinæ* (Bon., 1832) Gill, 1884.
   c. *Spinachiinæ* Gill, 1862.
304. Aulorhynchidæ Gill (1862), 1872.

(**Aulostomoidea**).

305. Aulostomidæ (Latreille, 1825) Gill, 1872.
306. Fistulariidæ (Bon., 1832) Gill, 1872.

(**Macrorhamphosoidea**).

307. Macrorhamphosidæ (Bikr., 1879) Gill, 1884 = Centriscidæ (Raf., 1826) Gill, 1872.

(**Amphisiloidea**).

308. Amphisilidæ (Bleeker, 1859) Cope, 1872.

Order **LOPHOBRANCHII**.

Suborder SOLENOSTOMI.

309. Solenostomidæ Kaup.

Suborder SYNGNATHI.

310. Syngnathidæ (Raf., 1810) Nardo, 1845.
   a. *Syngnathinæ*.
   b. *Siphostominæ*.
   c. *Nerophinæ*.
311. Hippocampidæ (Nardo, 1844) Cope, 1872.
   a. *Solegnathinæ*.
   b. *Hippocampinæ*.

Order **PLECTOGNATHI** (Cuv. 1817).

Suborder SCLERODERMI (Cuv., 1815) Gill, 1872.

312. Triacanthidæ (Bleeker, 1859) Cope, 1870.
   a. *Triacanthodinæ* Gill, 1862.
   b. *Triacanthinæ* (Hollard, 1860) Gill, 1884.
313. Balistidæ (Raf., 1810) Cope, 1870.
   a. *Balistinæ* (Raf., 1815) Gill, 1861.
   b. *Monacanthinæ* (Nardo, 1844) Gill, 1861, 1864.
   c. *Psilocephalinæ* (Bleeker, 1866) Gill, 1884.

Class TELEOSTOMES, ETC.—Continued.

Subclass TELEOSTEI—Continued.

Order **PLECTOGNATHI**—Continued.

Suborder OSTRACODERMI Gill, 1872.

314. Ostraciontidæ (Raf., 1810) Nardo, 1844.

Suborder GYMNODONTES (Cuv., 1817) Hollard, 1857.

(**Triodontoidea.**)

315. Triodontidæ (Bleeker, 1865) Gill, 1872.

(**Tetraodontoidea.**)

316. Tetraodontidæ (Bon., 1832) Gill, 1884.
   a. *Tetraodontinæ* (Bon., 1838) Gill, 1884.
   b. *Colomesinæ* Gill, 1884.
317. Canthigasteridæ Gill, 1892 = Psilonotidæ Gill, 1884.
318. Chonorhinidæ Gill, 1884.

(**Diodontoidea.**)

319. Diodontidæ (Bibron, 1855) Cope, 1872.

(**Moloidea.**)

326. Molidæ (Ranzani, 1837) Claus, 1882 = Orthagoriscidæ Bon., 1838.

Class TELEOSTOMES, ETC.—Continued.

Subclass TELEOSTEI—Continued.

Order **PLECTOGNATHI**—Continued.

Order **PEDICULATI** (Gill, 1865).

(**Lophioidea.**)

321. Lophiidæ (Raf., 1810; Bon., 1832) Swainson, 1839.

(**Antennarioidea.**)

322. Antennariidæ Gill (1863) 1878.
   a. *Antennariinæ* Gill, 1861, 1863.
   b. *Brachionichthyinæ* Gill, 1863.
   c. *Chaunacinæ* Gill, 1863.
323. Ceratiidæ Gill, 1863.
   a. *Ceratiinæ* Gill, 1861, 1878.
   b. *Oncirodinæ* Gill, 1878.
   c. *Himantolophinæ* Gill, 1861, 1878.
   d. *Œgaonichthyinæ* Gill, 1878.
   e. *Melanocetinæ* Gill, 1878.

(**Maltheoidea.**)

324. Onchocephalidæ Gill, 1892 = Maltheidæ (Bleeker, 1859) Gill, 1863
   a. *Onchocephalinæ* Gill, 1892 = *Maltheinæ* Gill, 1861, 1863.
   b. *Halieutæinæ* Gill, 1863.

NATIONAL ACADEMY OF SCIENCES.

VOL. VI.

SEVENTH MEMOIR.

HUMAN BONES OF THE HEMENWAY COLLECTION IN THE UNITED STATES ARMY MEDICAL MUSEUM.

THE HUMAN BONES OF THE HEMENWAY COLLECTION IN THE UNITED STATES ARMY MEDICAL MUSEUM AT WASHINGTON,

BY

DR. WASHINGTON MATTHEWS,
SURGEON, U. S. ARMY,

WITH OBSERVATIONS ON THE HYOID BONES OF THIS COLLECTION

BY

DR. J. L. WORTMAN.

REPORTS PRESENTED TO THE NATIONAL ACADEMY OF SCIENCES, WITH THE APPROVAL OF THE SURGEON-GENERAL OF THE UNITED STATES ARMY,

BY

DR. JOHN S. BILLINGS,
SURGEON, U. S. ARMY.

In 1887 an expedition was fitted out under the direction of Mr. Frank Cushing, with funds supplied by the liberality of Mrs. Mary Hemenway, of Boston, for exploring certain ruins in the valley of the Gila River, in the Territory of Arizona.

The work of exploration was commenced with a mound of large size, apparently little more than a rude pile of earth, in the valley of the Salado, or Salt River, a tributary of the Gila. This proved to be the ruins of a large earthen house, apparently analogous in structure to the still standing Casa Grande, which lies about 35 miles to the southeast, and these ruins were found to be a part of a congregation of houses or a city, extending about 6 miles in length, and from half a mile to a mile in width along the valley. A large number of human bones were found under the floors of the houses, so large a number, in fact, that Mr. Cushing gave the place the name of Los Muertos, or the town of the dead.

When the work was fairly under way Mr. Cushing was taken sick, and application was made by the Hemenway Exploring Expedition to the Surgeon-General to allow Dr. Washington Matthews, of the Army, to go out and take Mr. Cushing's place during his illness, to supervise the explorations. Dr. Matthews went to Los Muertos in the month of August, 1887. He found that no attention had been paid to the collection or preservation of human bones, which were extremely fragile, crumbling to dust upon a touch, and which had been thrown about and trampled under foot by curious visitors, so that but little remained of value from the work which had been previously done. Recognizing the importance and interest of these remains, he set to work to preserve the bones excavated after his arrival as far as possible, and reported the facts to me, suggesting that, if possible, the anatomist of the Army Medical Museum, Dr. J. L. Wortman, should be sent out furnished with means for preserving these bones as fast as they were excavated, and carefully collecting and forwarding them to the Army Medical Museum for study.

In accordance with these suggestions Dr. Wortman went out in November, 1887, taking with him a supply of silicate of soda, glue, paraffin, and other materials for saturating and preserving the bones which should be discovered, and remained with the expedition, visiting several other localities, until June, 1888, when he returned to Washington.

The specimens of human bones thus obtained were carefully packed and forwarded to the Army Medical Museum, and after having been repaired and put in the best possible form, were examined and measured by Dr. Matthews, and his report of the results is herewith presented by authority of the Surgeon-General.

JOHN S. BILLINGS,
Surgeon, U. S. Army, Curator Army Medical Museum.

INTRODUCTION.

When we began the study of the bones described in this work we had reason to hope that a full general account of the expedition on which they were discovered, with its archæological labors and achievements, would be published simultaneously with, or in advance of, this report; in which case we should have embodied in this essay the results of our anthropometric studies only. But the continued illness of the director of the expedition, Mr. Frank Hamilton Cushing, has caused the indefinite postponement of the preparation of a general report, and we consequently have considered it advisable to present here a short introduction, setting forth the inception, objects, and results of that scholarly enterprise, short-lived, but fruitful in its results, which was known as the Hemenway Southwestern Archæological Expedition.

Along the great cordillera of the American Continent on both sides of the equator, through 75° of latitude, from Wyoming to Chile, extends a land abounding in ancient ruins.

A large part of this land of ruins lies within the boundaries of the United States. It contains the Territory of Arizona, most of Utah, more than half of New Mexico, extensive parts of the States of Colorado and Nevada, with small portions of Texas, and, perhaps, of California. Its precise boundaries are not known, for on its outskirts there is much wild and imperfectly explored country where the existence of ruins can neither be affirmed nor denied. Its approximate boundaries are: On the east, longitude 28° west (from Washington); on the west, longitude 38° west; on the north, latitude 41° north, and on the south the northern boundary of the republic of Mexico, 31.20° to 32° N. L. It covers about 400,000 square miles.

The great rivers which drain it into the ocean are the Colorado on the west and the Rio Grande on the east; the former flowing toward the Pacific, the latter toward the Atlantic. But much of the rain which falls on its surface does not reach the ocean; some is received in salty lakes which have no outlets; some goes to form streams which reach the great rivers only in seasons of abundant rain, but which at other times after a brief course are absorbed by desert sands. It is an arid region, but not an absolute desert such as Gobi and Sahara. There is no part of it where rain does not fall some time during every year; but it is on the high mountains only that it descends abundantly; on the lower levels the precipitation of moisture is scanty, the dry seasons are long, and irrigation is essential to success in agriculture.

It has long been known that there were ruins in this arid region of the southwest. The earliest travelers, beginning with the Spanish conquerors of A. D. 1540, make mention of them, and their existence is noted in the reports of various military expeditions and public surveys which have entered this region since it was acquired by the United States from Mexico in 1848. The ruins have been known to the world for three centuries and a half; they have been in the possession of the United States for over forty years, yet it is only within the past four years (since April, 1887) that any attempt at systematic excavation has been made among them. In many of the better preserved ruins those portions which remained above the ground had been sketched, lithographed, photographed, engraved, surveyed, measured, modeled, and described, but the surface of the ground around and within them had not been broken. This method of examining them remained for the Hemenway Expedition to initiate.

The reasons for this tardiness on the part of our archæologists are numerous. This land of ruins was until recently wild, barren, and difficult of access; it was held largely by tribes of hostile Indians who to this day are not perfectly subdued. It is only within the last decade that

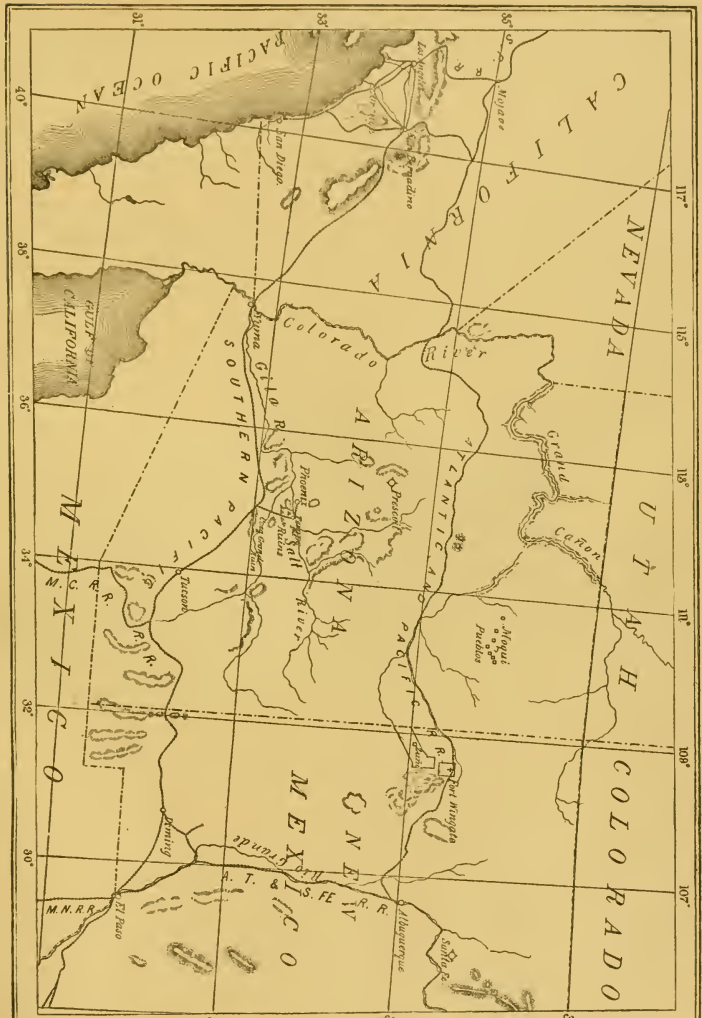

FIG. 1.—Map of southwestern portion of United States showing field of operations of the Hemenway Southwestern Archæological Expedition.

it has been crossed by railroads. Explorations within its borders were attended with many physical difficulties. The parties of topographical surveyors who entered the country had very short seasons in which to work, and they had neither the time nor means, had they had the inclination, to make the needed excavations. But besides physical hindrances there were others equally potent. The importance of excavation to the proper understanding of the archæology of this region was not appreciated; surface finds were numerous and interesting, and it was thought that excavation could yield nothing further. The majority of antiquarians in America were more deeply interested, as they still are, in the exploration of the old world than in that of the new. Money which was readily forthcoming for the one was withheld from the other by patrons of science in America.

The few explorers who were interested in work within our own borders found sufficient field for their labors and speculations in the mounds and kitchen-middens of the Eastern States. It was at length, through the unsatisfied curiosity of the ethnographer, not through the zeal of the archæologist, that the systematic exploration of the Western ruins was begun.

The region in question abounds in finely stratified sandstone, which with little labor may be prepared for building, and most of the ruins so far discovered are the remains of houses built of such stones. These may be found in all stages of decay—in some cases the walls are still standing many stories high, as in the valley of the Chaco; in other cases the sites are marked only by low heaps of lichen-covered stones, indistinguishable, save to the trained scientific eye, from natural accumulations of rocky *débris* with which the country abounds. Some of these ruins were

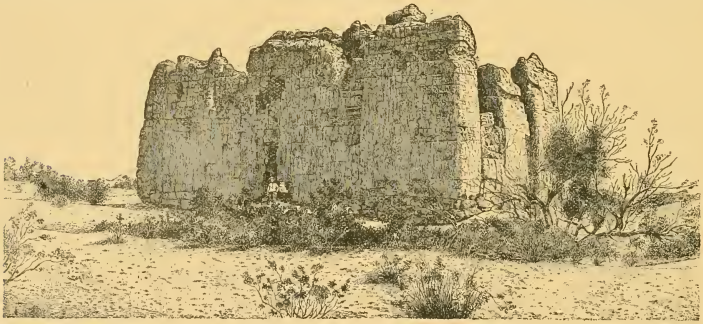

FIG. 2. The Casa Grande of the Gila.

inhabited by Indians within the brief historic period of New Mexico and Arizona, which extends over less than four centuries, but the vast majority are prehistoric. A number of the ruins are those of houses whose walls were of clay (*adobe* and a variety of *pisé*). Some of these in the valley of the Rio Grande were built since the Spanish occupation of the country and many have been erected under civilized guidance, but others, particularly those in the valley of the Colorado, are undoubtedly of prehistoric and aboriginal origin. As might be expected the earthen walls are in many cases reduced to the common level of the ground and are to be traced only, as in the ruined cities of the Salado, by digging beneath the surface of the earth; yet one of the best preserved and most imposing of the prehistoric ruins within our borders, the Casa Grande of the Gila (Fig. 2), is built of clay. This ruin was long supposed to be the remains of a structure without counterpart within the boundaries of the United States; but, as will hereafter be shown, it is now known to be but one of many such buildings which once towered over the wide flood-plains of the Gila and its tributaries.

In studying the folklore and religious practices of the people of Zuñi during his residence of about five years in their pueblo, Mr. Cushing found himself confronted by many perplexing questions for which no satisfactory explanation could then be found; but he was led to believe from

the traditions of this people that some key to the problems might be discovered by exploring ruins far to the southwest of the Zuñi villages, where the people of Zuñi averred their ancestors once dwelled. We can not enter into a detailed account of these perplexing questions, nor can we relate how or why the explorer considers that he has solved them. It must be left for him to explain these matters fully at some future time.

EXPLORATIONS IN THE SALADO VALLEY.

It was not until the year 1886 that he found the pecuniary means to conduct the desired explorations, these being amply supplied by Mrs. Mary Hemenway, of Boston. Mr. Cushing set out with a party of assistants, to which others were afterwards added, and, in February, 1887, arrived in the neighborhood of the town of Tempe, in the valley of the Salado or Salt River, a tributary of the Gila, in the Territory of Arizona. Here he began by excavating some stone ruins on the rocky uplands, without any extraordinary results, While thus engaged his attention was attracted to certain earthen mounds situated on the level flood-plain of the Salado, and in particular to one of large size about 8 or 9 miles by road from Tempe. He proceeded to examine this mound and its vicinity.

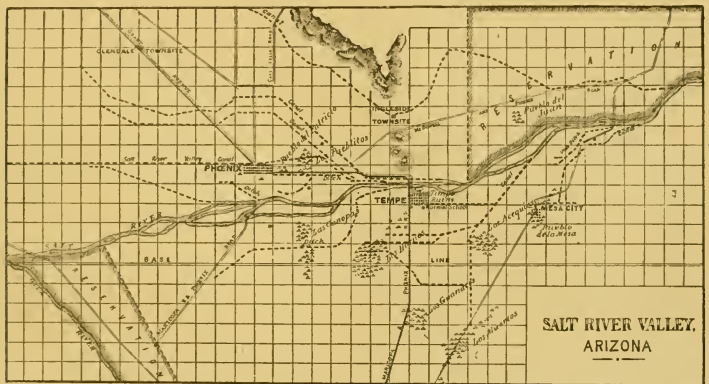

FIG. 3.—Map showing a part of the Salt River Valley, Maricopa County, Arizona, with modern towns, canals, and locations of ancient cities.

This mound seemed at first to be little more than a rude pile of earth. It had an irregular rectangular form, and had some appearance of being terraced. The surrounding level plain, covered with an abundant growth of that leguminous shrub or small tree, the mesquite (*Prosopis juliflora* D. C.), which is so common in the arid lands along our southwestern borders, presented to the untrained eye no remains of human habitation; but from fragments of pottery and other objects strewn over the ground, the explorer was led to believe that something of importance was hidden under the surface. He caused a trench to be dug and soon brought to light the foundations of earthen walls. Without delay he established his camp at this place and pursued his excavations with energy. The result was the discovery of an extensive collection of habitations—a city it might be called—some 6 miles in length and from half a mile to a mile in width. The mound proved to be the *débris* of a great earthen house of many stories and many chambers and analogous in structure to the still standing Casa Grande before referred to, which is distant from the mound to the southeast less than 35 miles in a direct line. In the course of excavation at this place so many skeletons were found under the floors of the houses that Mr. Cushing devised for it the Spanish name of Pueblo de los Muertos, or, briefly, Los Muertos, the town of the dead; and this name was retained for it, although he subsequently found other ruined cities in the vicinity where skeletons were as common as here.

Work was continued in the valley of the Salado or Salt River until June 1888, a period of about sixteen months. During this time, besides isolated ruins and small groups of ruins, the party discovered the remains of six other large cities within a distance of about 10 miles from that first discovered. Of these, three were named: First, Las Acequias from the number, size, and distinct appearance in its vicinity of the old acequias or irrigating ditches through which the departed inhabitants conducted water to their fields; second, Los Hornos or The Ovens, from the number of earthen ovens found there, and third, Los Guanacos, because in it were found small terra-cotta images of animals thought to resemble the guanaco of South America. In these ruined cities the remains of other buildings like the Casa Grande were found.

HOUSES.

The houses in these cities were of four kinds, designated by Mr. Cushing as follows: 1, priest temples; (2) sun temples; (3) communal dwellings and (4) ultra-mural houses.

The priest temples.—These were the most conspicuous buildings in the ancient cities. As a rule there was only one to each city, and this was centrally located; but in one of the cities observed there were seven such buildings, the largest of which was centrally located. The reasons for this peculiar distribution, Mr. Cushing believes, are explained by Zuñi folklore and modern Zuñi customs. The ruins gave evidence that the buildings, when standing, were many stories high—from four to seven stories it is estimated The Casa Grande on the Gila is said to show traces of five floors in that portion of its walls which still remain, and it is probable that one or two stories have fallen. Each building was surrounded by a high rectangular wall from 5 to 10 feet thick. A portion of this wall remains, and, being filled with the *débris* of the fallen building within, lends to the mound-like ruin that terraced appearance before alluded to. The lower story in each building was divided into six apartments, four great and two lesser. These apartments, the explorer believes, were used as store rooms for the priestly tithes in maize, etc. The other stories are supposed to have been used for priestly residences and for sacerdotal purposes. The entire building is thought to have served, not only as a storehouse and temple, but as a fortress in times of danger. Besides these in Arizona, there are great houses of similar construction in Sonora and Chihuahua, in northern Mexico.

The manner in which these buildings were constructed is perhaps peculiar. They might be regarded as great mud-covered baskets. For the thicker walls two rows of posts were erected and secured, one post to another, in different directions, by means of smaller sticks firmly lashed to them. The framework thus constructed was wattled with reeds, so as to form two upright hurdles braced together. The space between these was filled with well-packed mud, and the hurdles were thickly plastered within and without with the same substance. The thickness of the wall depended on the distance between the hurdles. For the thinnest walls, the internal partitions, but one hurdle was erected, and this was plastered on both sides. These structures of wood and reed no longer remained when the excavations were made, but the cavities found in the walls gave evidence of their former existence.

Sun temples.—The buildings which Mr. Cushing designates by this name, though not as lofty as the priest temples, covered a greater superficial area. The smallest measured was 50 feet in width by nearly 100 feet in length. One was discovered whose dimensions were about 150 feet in width by over 200 feet in length. Like the priest-temples they were built of earth on a great basket form or frame of hurdles; but the basket form instead of being rectangular was elliptical in shape. There is evidence that this frame of hurdles gradually tapered toward the top, and that the structure was roofed in with a dome made of a spirally contracting coil of reeds, resembling the coil baskets now so commonly made by the various tribes of the southwest. This spiral coil, as well as the rest of the frame, was heavily covered outside with mud, so that the structure when finished must have appeared, as Mr. Cushing expresses it, like an unburned, inverted and elongated terra-cotta bowl. The floor was elevated at its edges so as to form a sort of amphitheater and in the center was a hearth. It is thought that in these buildings the public rites of esoteric societies were performed as well as the sun drama and other ceremonies. The sun temples were usually in close proximity to the priest temples, and their ruins presented the appearance of low oval mounds depressed in the center.

Communal houses.—The great structures thus designated were the principal dwelling places. They were built of mud without the central frame of hurdles on which the walls of the temples were raised. They contained many rooms on the ground floor, and, as there is evidence that they were sometimes more than one story high, it is not improbable that they resembled much the modern terraced pueblos of New Mexico and Arizona. They were too large for the dwellings of single families, and for this and other reasons they are thought to have been each the home of a separate gens, clan, or some other large subtribal division. Each was surrounded by a separate high earthen wall and generally by a separate canal or acequia, although, in a few instances, two or more communal dwellings were included in the same encircling canal. Each had its single appropriate water reservoir with a branch canal leading into it, its one separate pyral mound or place of cremation, and its one great underground oven for the preparation of food. In Los Muertos at least fifty of these great buildings were wholly or partially unearthed, and it is likely that many more remained unrevealed beneath the surface of the ground.

Ultra-mural houses.—These were small, low huts, not rectangular in form, made of sticks, reeds, and similar perishable material, lightly coated with mud, and they probably resembled much the modern *jakal* or hut of the lower classes in many parts of Mexico, or the houses of the present Pima Indians of the Gila Valley. Mr. Cushing calls them ultra-mural or ultra-urban because they were situated outside the limits of the towns of earthen houses and not mingled with them; they formed separate groups. He conjectures that they may have been residences of an outcast population such as exists at Zuñi to-day. As each contained a central fireplace it is evident that they were occupied in winter as well as in summer, and were, therefore, not like certain houses scattered through the fields of the modern Zuñis, used only as temporary shelter for laborers while the crops are growing. These ultra-mural dwellings were very numerous; in one place constituting, of themselves, a town of considerable size, which contained a sun temple but no priest temple. In estimating the age and character of some, at least, of these houses, it must not be forgotten that as late as the seventeenth and eighteenth centuries we have records of the existence of Pima villages in the lower part of the Salt River Valley. I make this statement on the authority of Mr. Bandelier.

AGRICULTURE AND WATER SUPPLY.

When these ruins were inhabited cities, the land in which they lie was, as it now is, an arid region, where agriculture could not be conducted without irrigation. The works constructed by the ancient inhabitants to establish irrigation are as noteworthy monuments to their industry and intelligence as are their stupendous buildings. The explorers have traced in this particular realm in the Salado Valley, they estimate, over 150 miles of the larger canals—the mother acequias or *acequias madres*, as the Spanish-Americans call them. Their remains have been found at distances of 12 and 15 miles from the present bed of the river, and there is no evidence that the river has materially changed its course since the days of the ancient inhabitants. The miles of smaller acequias could not be estimated.

The larger canals varied in width from 10 to 30 feet and in depth from 3 to 12 feet. Their banks were terraced in such form as to secure always a uniform central current in the canal when the rains ceased in the mountains and the waters diminished. It is thought that this device was to facilitate navigation, and that the canals were used not only for irrigation, but for the transportation of the produce of the fields and of the great timbers from the mountains which the people must have needed in the construction of their tall temples and other houses.

In various parts of our arid region the old Indian canals may be still easily traced where they are cut through hard soil or where they are so exposed and situated, with regard to the prevailing winds, that the sand is blown out of them rather than drifted into them. There are places in Arizona where the American settlers utilize old canal beds for wagon roads. But in most cases the canals have been filled with sand and clay to the level of the surrounding soil and, to the ordinary observer, no vestige of them remains. Yet Mr. Cushing, guided by his knowledge of a custom which exists among the Zuñi Indians, was able to trace the course of these obliterated channels. These Indians, he relates, have observed that wherever there is running water there are rounded pebbles and boulders; reasoning, as man is so apt to do, inversely to the natural order

of causation, they suppose not that the waters shape and deposit the pebbles, but that the pebbles control and direct the flow of the waters. For this reason they place such stones on the margins of their artificial water courses to hasten and direct the current. The presence of these pebbles disposed in lines, at the surface of the ground, caused the explorer to surmise that they marked the sites of irrigating ditches, and excavation proved the surmise to be correct. Pebbles which had once been used as implements and become worn out or broken in service were those most usually employed for this purpose.

Within the past twenty years, since the wild Indians of western Arizona have been subdued and order has been established within that region, the locality in which Los Muertos and its neighboring cities lay has been again restored to cultivation—this time by the white race, who utilize, through new channels, the waters of the same Salt River that fed the fields of the departed races. The canals of the moderns follow straight lines; those of the ancients were tortuous; but the ancient people used the water to greater advantage than their successors and covered with their system a wider territory. In the old canals the fall was about 1 foot to the mile, in the new it is 2 feet to the mile. The ancients constructed great reservoirs to store the excess of water when the river was high; the present occupants have no such works. Since this region has been reclaimed it has proved one of the most fruitful within the boundaries of the United States and is adapted to a wide range of vegetation, temperate and tropical.

In one place, near the present Mormon settlement of Mesa City, about 10 miles from the ruins of Los Muertos, the canal was dug through a hard, rocky layer. The Mormon community made use of the prehistoric cut when constructing their own irrigating ditch. I have heard on good authority that the Mormons estimate the labor thus saved to them at $20,000. Who will calculate the equivalent of this in human hands and days of work during the age of stone and when man was his own beast of burthen?

In addition to the river irrigation the ancient Saladoans had a system of rain-water irrigation. In the woodless mountains immediately surrounding their homes, the Superstition Mountains, the Estrellas Mountains, etc., brief but heavy rains sometimes fall, which flow at once into the plain, causing heavy floods and doing more damage than benefit to the crops. In these mountains there are neither springs nor constant water courses and only a desert flora. The heights which give birth to the Salado and the Gila are farther away and of much greater altitude. To conserve the waters of these sudden rains in the neighboring hills the people built dams in the ravines and large reservoirs in suitable places in and near the neighboring foothills. From these reservoirs the waters were, when needed, allowed to flow gradually over the fields. This may be regarded as evidence that the waters of the rivers, abundant though they were, were not sufficient for the needs of the population.

BURIALS.

The bodies of the dead were buried both with and without previous cremation. Those buried without cremation were always buried in the houses, either under the ground floors or in the walls. The cremated remains were interred outside of the houses.

The wall or mural burials were found mostly in the priest temples, in what remained of the first and second stories; a few were discovered in the communal dwellings. The body in such a burial was inclosed in an adobe case, and a niche was cut in the wall for its reception, which was afterwards filled and plastered over with mud, so as to leave no external evidence of the burial.

The burials under the floors were confined to the communal dwellings. The graves were constructed with different degrees of care; the more perfect being rectangular holes carefully plastered on the sides with mud and sealed over with the same material. The dead were usually placed with their heads to the east and slightly raised or pillowed so that the faces were turned toward the west. The hands were laid at the sides or over the breast. The lower extremities were placed as we place those of our dead except in one instance, that of an adolescent female who was supposed to have been sacrificed to the gods to avert earthquake. She was buried with the limbs abducted.

In a few instances in the communal dwellings the body was buried partly under the floor and partly in the wall. This was supposed to be for the purpose of economizing space. The trunk,

in a supine position was buried close to the wall; the lower limbs, elevated at right angles to the trunk, were placed in a niche in the wall which was then filled up with mud.

Among those buried under the floors, many were children, and these were found always buried near the kitchen hearths. This is a custom which is found to have prevailed in other parts of the world and is variously accounted for. Mr. Cushing's explanation derived from Zuñi folklore and belief is this: "The matriarchal grandmother or matron of the household deities is the fire. It is considered the guardian as it is also, being used for cooking, the principal 'source of life' of the family. The little children, being considered unable to care for themselves, were placed, literally, under the protection of the family fire that their soul-life might be nourished, sustained, and increased."

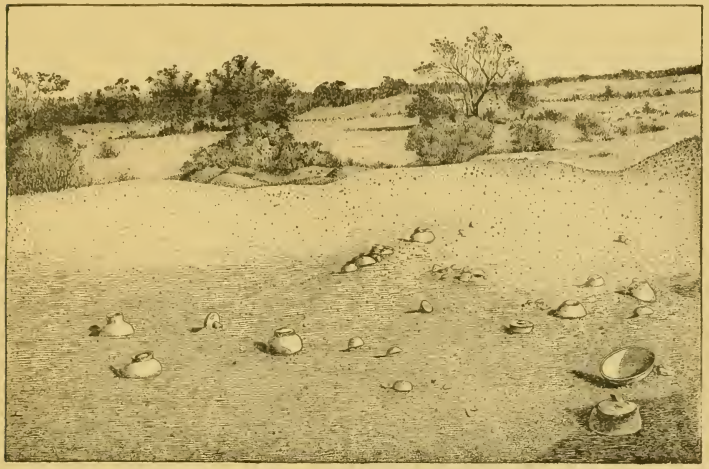

FIG. 4.—Pyral cemetery, unearthed.

Within both the underground and wall sepulchers were found deposited various household utensils, articles of personal adornment and others of a sacerdotal character. In the mural burials of the temples the articles of sacerdotal use were particularly numerous and elaborate. This is one of the many reasons Mr. Cushing has for believing that those buried without cremation were of a sacerdotal and higher class of the community, while those who were cremated were of a lower class, and laymen. The pottery buried with the adults in the graves, was left whole and not broken or "killed" in the manner to be described when speaking of burials after cremation; that buried in graves with children was, however usually "killed" or broken. The sacred paraphernalia referred to were so similar to those used in Zuñi to-day that Mr. Cushing "was often able, through the knowledge of the Zuñi priesthoods to identify the medicine or priestly rank of the silent occupant of a sepulcher."

The great majority of the dead were cremated. Each communal dwelling had in close proximity to it, its own pyral mound and, situated at the base of the latter, a collection of earthen vessels containing the remains of the dead—a pyral cemetery (Fig. 4). The mounds consisted of ashes, cinders, and fragments of charred and broken mortuary sacrifices; they were from 60 to 100 feet in diameter, from 3 to 9 feet high and showed evidence of having had from 2 to 6 locations for pyres in each. That each pyral mound was appropriate to its neighboring communal house

was inferred from the correspondence of certain special marks and designs on the pottery in the pyral cemetery with designs found on pottery in the graves of the contiguous dwellings.

The burnt bones and charred remains of some of the more valued articles of personal property were placed in pots of suitable size, which were covered by inverted bowls or broken pieces of pottery and surrounded by other articles of pottery buried as presents to the dead. These mortuary gifts were broken or drilled before burial, probably in order that the souls they were thought to possess might escape and accompany the dead to the spirit land. The custom of breaking the pottery sacrificed with the dead is called by the people of modern Zuñi "killing" the vessels, and is still practiced among them.

It is believed that those of the priestly race were not cremated because they had the power to release their own souls from their bodies while the laity, having no such power, had to have their bodies burned to effect the desired release. Whatever may have been the creed that thus preserved some bodies for simple interment, anthropology owes it gratitude, for without it the unique skeletons of this archaic race would not have been preserved for modern study and comparison. It is thought, too, that the pots buried with the uncremated adults were not broken or "killed" because the priests knew how to release the souls of the pots and take them with them to the undiscovered country, while to the laity such knowledge was denied.

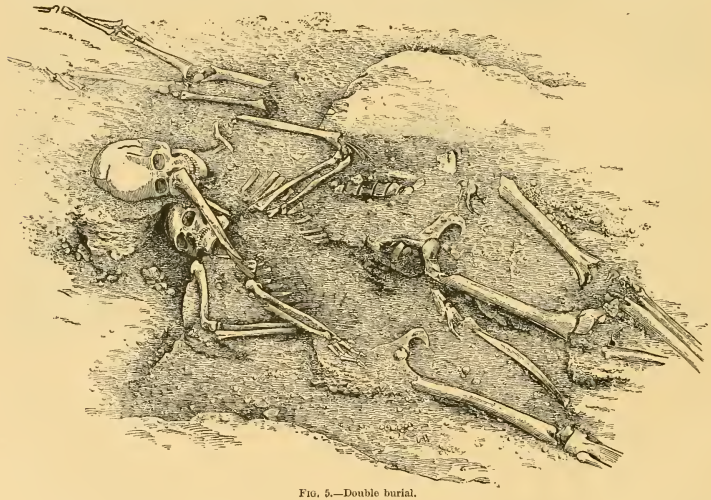

FIG. 5.—Double burial.

Double burials were found both with the cremated and the uncremated remains; but were much more common with the latter than with the former. When two skeletons were discovered in one grave or incinerary vessel they were invariably adult, and, whenever the sex could be determined, one was always found to be a male and the other a female—presumably man and wife. This might be thought to indicate that the wife had been sacrificed at the death of the husband; but in the house graves there was often evidence that the interments were not simultaneous, the upper grave not being dug exactly over the lower and the bodies having been apparently wrapped in different cerements. It was a rare thing to find three buried in one grave. Fig. 5 shows a double burial, male and female, in which the interments, and probably the deaths, were simultaneous.

ARTS.

Nearly all the implements and tools discovered were of stone, but of beautiful finish and great variety of form. No metal tools, whatever, were found. The only articles of metal were little rude copper bells.

FIG. 6.—Small water-jar, found in hearth sepulcher, buried with child, in Los Muertos.

A copper bell consisted of a plate of the metal wrought into leaflets. These leaflets were brought together at the apices so as to form a hollow ball with meridional openings. In this ball a pebble was imprisoned for a clapper. The handle, or stem, was soldered on in a manner which

FIG. 7.—Small water-jar, found buried with child in house sepulcher, southern portion of Halonawan, ancient Cibola.

indicated a knowledge of a soldering material and the use of the blowpipe; and indications are not wanting that the bells were not introduced from a distance by trade, but were manufactured where found.

Pottery was found in great abundance in the house graves, in the pyral cemeteries, and on the floors of the houses, where it seemed to have been abandoned, as if the dwellings were suddenly deserted. It consisted of food vessels and water vessels in a great variety of shapes and sizes, and of well-executed images of animals of the chase which once inhabited the surrounding

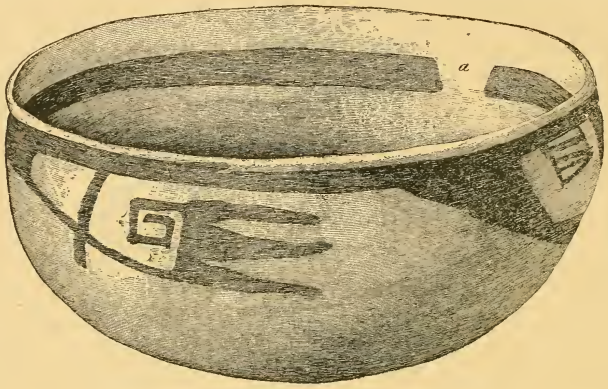

FIG. 8.—Ancient Cibola eating bowl, showing "exit trail of life."

country. The vessels were decorated in a manner closely resembling those of the modern Pueblos of New Mexico and Arizona, especially those of the Zuñi and Moqui (see Figs. 6, 7, 8, 9, and 10). The more commonly employed symbolic decorations were alike in all.

FIG. 9.—Modern Zuñi food bowl, showing "exit trail of life."

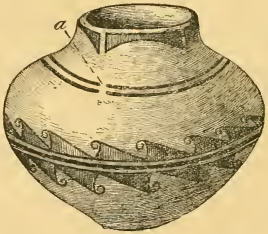

FIG. 10.—Modern Zuñi water vessel, showing "exit trail of life."

One of these, worthy of especial note, is what the Zuñis call the exit trail of life. It is found inside of food vessels and outside of water vessels; it consists of an opening or hiatus in the single or double encircling paint bands near the margin of the vessel, as shown at *a* in Figs. 8, 9, 10. It is a symbol based on the idea before alluded to of vessels having souls.*

* See Fourth Annual Report of the Bureau of Ethnology, p. 510.

Another decoration, shown in Figs. 11, 12, 13, may here be mentioned. It is undoubtedly an animal figure which in textiles and basketry has been necessarily conventionalized into a figure

FIG. 11.—Ornamental zone on water jar from Los Muertos.

bounded by straight lines, and from the woven forms transferred, more or less modified, in paint to the pottery. It is common on both the ancient and modern pottery of our southwestern land of ruins, and is frequently seen in the cloths of ancient Peru. (See Fig. 14.)

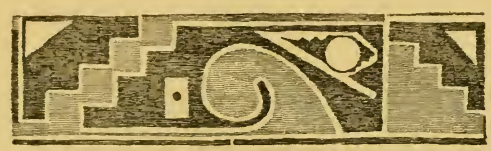

FIG. 12.—Symbolic decoration in white-bordered black, adapted from ornamental zone on water jar of red slip ware from Los Muertos.

The articles of personal adornment which remain are principally of shell and consist of rings, bracelets, pendants, etc. Some of these were ornamented with geometrical designs and inlaid

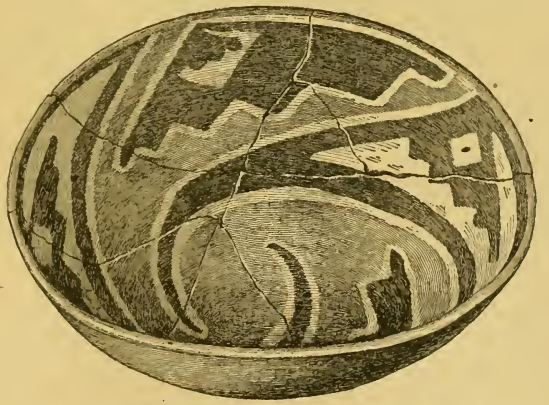

FIG. 13.—Medium sized eating bowl of red slip ware, with white-bordered black paint decoration. From Halonawan, one of the ancient seven cities of Cibola.

with turquois and other precious or semiprecious stones. Sea shells carved in the form of a frog were common and one or two of these frog images were beautifully inlaid with turquois and other

stones of brilliant color. The inlaying was accomplished by coating the shell with some black vegetable gum (supposed to be that of greasewood) which hardened on drying; the gems were stuck into this coating and, when the latter became hard, the whole was rubbed down to a smooth surface. An accurate chromo-lithographic illustration of one of these artistic objects has appeared in *Gems and Precious Stones of North America*, by George Frederick Kunz, New York, 1890.

Everything susceptible of decay in these ruins had disappeared; hence, with two or three trifling exceptions of charred and defaced articles, nothing was left of their woven stuffs, their basketry, their woodwork, or the featherwork. But that they wove cloth, wrought baskets and made useful and ornamental objects in various perishable materials, we have abundance of collateral evidence.

During the first fifteen months of the work of the expedition from 17,000 to 20,000 specimens of various kinds were collected, and many fragments rejected. But the collection would have been far richer were it not for the wanton destruction of much material by visitors. Sometimes when

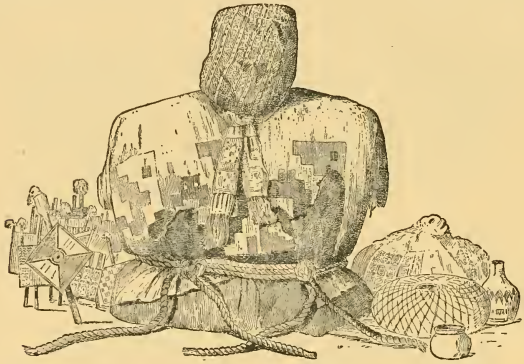

Fig. 14.—Mummy from cemetery at Ancon, Peru.

a pyral cemetery or the floor of a large dwelling had been unearthed, and all the articles discovered laid in their original positions to be photographed, a party of sightseers would appear and, either in the absence of the workmen or in spite of their remonstrances when present, trample the objects under foot or deliberately kick the pottery to pieces to "see what was inside." In the earlier days of the work many fine skeletons were lost in this way. Some persons even appropriated handsome objects and carried them away, maintaining that, as these things were found on public land, all had an equal right to them.

POPULATION.

What was the population which in ancient days subsisted on the crops watered by the Salado or Salt River and the stored rains of the neighboring mountains? What was the population of the old Salado settlement? Opinion is divided on this subject, and will probably long continue to be divided. Some who have had the best opportunities of observing the ancient works and studying the problem estimate the population at from 80,000 to 100,000 souls. Los Muertos, it is calculated, covered an area of over 2 square miles and contained about 13,000 inhabitants. There were six other groups of buildings in the region as large or larger than this, and there are indications that they were simultaneously occupied. If it could be shown that they were not occupied at the same time, a much lower estimate of the population would have to be made. As the land is

now becoming rapidly filled with white settlers, and the ancient town sites are being covered with farms and crossed with irrigating ditches, all antiquarian problems become more difficult of solution every day.

ANTIQUITY.

In 1539, when Friar Marcos made his journey to Zuñi, and when, a year later, Coronado marched with an army to the same point, they passed within about 100 miles of these towns. Had they been inhabited in those days, the travelers would doubtless have heard of them, for the fame of the less significant Seven Cities of Cibola reached them in the heart of Mexico and induced them to travel 200 miles further northeast than the mouth of the Salado. They were ruins, no doubt, three hundred and fifty years ago, or at the beginning of the historic period of Arizona. No vestige of anything belonging to the iron age or of European origin was brought to light in the excavation. The writer knows of other ruins in New Mexico and Arizona which, from recorded

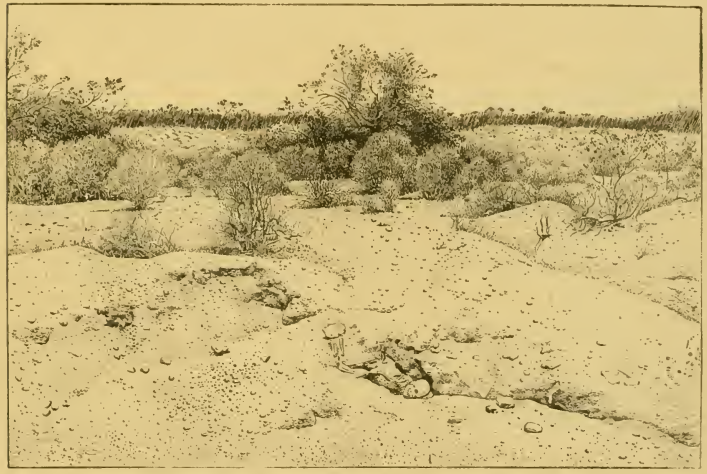

FIG. 15.—Skeleton of man supposed to have been killed by earthquake.

evidence, are known to have fallen to decay and been abandoned long before the historic period; yet in these textile fabrics and other perishable articles are still found fairly preserved, and particularly the hair of the dead has survived the process of decay. In Los Muertos were found no hair, no cerements, nothing that might have escaped destruction in a thousand years. It is thought by Mr. Cushing that from one thousand to two thousand years may easily have elapsed since the priests of Los Muertos worshiped in its standing temples. The Casa Grande of the Gila was a ruin standing in the sixteenth century probably much as it stands to day; three and a half centuries have wrought little change in it; but the similar priest-temples of the neighboring Salt River are mere mounds of earth. The writer has seen two photographs of the Casa Grande of the Gila taken from the same point of view, one twenty years after the other; yet in the pictures no difference can be discerned in the most minute points and prominences of the ruin, which were subject only to the modifying influences of rain and wind, though the parts within the easy reach of human hands have suffered notably.

It must be remembered that earthquake may have hastened the fall of the Salado temples. The explorers have found many indications that these cities were abandoned on account of earthquake, and Zuñi myth and tradition point to former migrations of the people induced by seismic disturbances. One skeleton in Los Muertos was found lying on its face, evidently of a person never formally buried, and apparently crushed by falling walls.* (See Fig. 15.)

FIG. 16.—Outline drawing, full size, of terra cotta image of animal, supposed to be allied to the vicuña.

It has been indicated in the previous pages that an intimate relationship in arts, civilization, religion, etc., has been found to exist between the ancient Saladoans and the ancient sedentary people of Arizona and New Mexico in general, as well as the still extant sedentary tribes of this region. A relationship, less intimate perhaps, may be shown to exist between them and the

FIG. 17.—Rock inscription thought to represent vicuña-like animals and man throwing *bolas*.

ancient house-building tribes of old Mexico and Central America. There are many facts, too, which point to a close connection between the Saladoans and the ancient Peruvians—a connection more close perhaps than that between the former and many races who lived nearer to them, geographically, than the Peruvians. Environment may have had its influence on this affinity, for

* Since the above was written it has become apparent that we may attribute the sudden destruction of these earthen buildings to floods as reasonably as to earthquakes. In the spring of 1891 this region was visited by a great flood, which covered much of the Salt River flood-plain and ruined many of the adobe houses of the white settlers.

the conditions surrounding human life in Peru are more like those of Arizona than those of tropical Mexico and Central America. The following are some of the indications of a special relationship between the ancient Peruvians and the ancient Arizonians:

1. In the ruins of some of the ultra-mural houses there were unearthed terra-cotta images of a quadruped which can not be identified as resembling any animal of the present North American fauna, while all other effigies found are easily identified. Unfortunately I am able to present only an outline drawing of one of these (Fig. 16.) Zoologists who have seen the original terra-cottas are of the opinion that it represents a creature allied to the South American *camellidæ* (llama vicuña, guanaco, etc.). In various parts of the Southwest there are petrographs which are thought to represent the same animal. Some of these petrographs are located at considerable distances from Los Muertos, as, for instance, those in the Puerco Valley, some 250 miles away.

FIG. 18.—Rock inscription representing, it is supposed, vicuña-like animals and bola-thrower, besides deer and other animals.

It has been surmised that such animals continued to be domesticated by the sedentary Indians of Arizona and New Mexico down to historic days and became extinct only when the more serviceable European sheep was introduced by the Spaniards. This surmise is based on certain statements found in the works of early writers and explorers who speak of the Pueblo Indians having a coarse cloth, something like woolen cloth, and having small wool-bearing animals domesticated in their houses. But Prof. Bandelier, who has studied the early documentary evidence relating to the Southwest more thoroughly, no doubt, than any other living student, discredits the modern existence of these animals. In a letter to the writer he shows that we have only hearsay testimony as to their existence and concludes with these words: "If there has ever been a llama, guanaco, or vicuña, known to the Southwestern Indians, it became extinct long previous to the sixteenth century." Fossil bones of an animal of this family have been found in the Southwest; but its bones were not identified in the Salado ruins.

2. In several places among the ruins, on the floors of the houses, near the walls (as if they had fallen from the latter), were seen peculiar groups of stones, consisting of three globoid and one ovoid pebble. These are thought to have been the stones of *bolas* such as are now used in South America to catch wild or half domesticated animals. The buckskin cases and thongs which connected the stones are supposed to have decayed, like all similar material in the ruins. The presence of these stones would, in itself, be insufficient evidence of the use of *bolas* among this people, but

it is thought that the petrographs afford additional testimony. Where these vicuña-like animals are delineated on the ancient rock-carvings, they are often associated with the figure of a man holding in his hand a peculiar four-branched instrument; one of the branches is held by its extremity in the hand, the others are in the air (Figs. 17, 18, and 19). This is thought to depict a herdsman or hunter in the act of casting the *bolas*. The *bolas* have, as far as can be ascertained, not been in use in North America south of the Artic circle since the Columbian discovery, although an implement, analogous in use but different in form, is employed by the Eskimo.

FIG. 19.—Rock inscription of supposed bola-thrower, dancing men, and other objects.

Fig. 20 is a copy of a rock inscription showing a number of these animals associated with a hunter bearing a bow. Fig. 21, also from a rock carving, represents a supposed bola-thrower in connection with a flock of turkeys. The turkey is found wild in Arizona and was probably domesticated by the ancient inhabitants of the country.

FIG. 20.—Rock inscription of vicuña-like animals and hunter.

3. In sacrificial caves in mountains surrounding the Salado cities, knotted cords have been found which are much like the *quipus* used by the ancient Peruvians. Similar knotted cords are still in use by the people of Zuñi and are by them called kispuwe, a name very similar in sound to the Peruvian.

4. In addition to these indications we must consider the great and closely corresponding prevalence of the *os Incæ* in the skulls of these two widely separated peoples. This is a subject discussed more fully in the somatological part of this work.

EXPLORATIONS NEAR ZUÑI.

The expedition left the Salt River Valley in June, 1888, and arrived at Zuñi in the following month. The work was continued in the vicinity of this place under the direction of Mr. Cushing until October 20, 1888, when he left for the East. His physical condition was such that he was not able to return; but the work of excavation was continued in his absence until July, 1889, at which time the expedition was disbanded.

The location of the Seven Cities of Cibola, visited by Coronado in 1541, was long a question for scientific discussion, and many arguments were advanced in favor of different places; but the ethnologic researches of Mr. Cushing and the historical investigations of Prof. Ad. F. Bandelier have settled the question beyond a reasonable doubt. The Seven Cities were situated in the valley of the Zuñi River in the neighborhood of the present pueblo of Zuñi, in Valencia County, N. Mex. The accompanying map (Fig. 22) shows very approximately the location of each. It was prepared with the assistance of Mr. F. Webb Hodge, of Washington, formerly secretary of the expedition.

FIG. 21.—Rock inscription, turkeys, supposed bola-thrower, etc.

We give below a list of the names of the cities in the modern Zuñi language, as noted by Mr. Cushing, and in the old Zuñi or Cibola language, as noted by Coronado and other Spanish travelers and writers of the sixteenth and seventeenth centuries. If we make due allowance for the difference between a carefully devised modern orthography and a haphazard spelling of three hundred years ago we need not suppose that the language of Cibola has changed materially during the intervening time.

NAMES OF THE SEVEN CITIES OF CIBOLA.

	Modern.	*Sixteenth and seventeenth centuries.*
1.	Hàwiku	Ahacus, Avicu, Aquico, Jahuico, Havico.
2.	Kyànawe, Hampasawan	Canabe.
3.	Ki-tchupawe, Kwàkiina	
4.	Apina, Pinawan	Aquinsa.
5.	Hàlona, Hàlonawan	Alona.
6.	Màtsaki	Muzaqui, Maçaque, Maçaquia.
7.	Kyàkima	Caquina, Kyakima.

It was the original intention to explore all the ruins of the Seven Cities; but the illness of the director and the consequent recall of the expedition prevented the fulfillment of this plan. Only one of the ruins of the seven cities was explored to any extent, namely, the ruin of Hàlona. This town occupied in part at least the site of the present pueblo of Zuñi. The excavations were made

upon the opposite bank, from Zuñi, of that meager and inconstant desert streamlet known as the Zuñi River and in the neighborhood of houses occupied by the present ultra-urban population of the Zuñi tribe.

Explorations were conducted in other ruins in the neighborhood. Some slight digging was done in those on the top of Inscription Rock; but the most work was accomplished at Hèshota-ùthla, a ruin on the road to Wingate, some 12 miles in a northwesterly direction from Zuñi. Hèshota-ùthla was in its day a compactly built, many-storied stronghold of stone containing a

FIG. 22.—Zuñi towns, ruins of Cibola and other ruins.

population of probably more than a thousand people. It was not one of the Seven Cities; but, according to the traditions (corroborated by archæological investigation) of the Zuñi Indians, it was occupied by their people in a remote antiquity. From this ruin was derived the greater part of the "Cibola" skeletons described in the second part of the following report.

In preparing this introduction, the writer has had access to some of Mr. Cushing's notes, especially to the original manuscript of a paper contributed to the Berlin meeting of the Congress of Americanists in October, 1888, and he has consulted a pamphlet entitled "The old New World," an account of the explorations of the Hemenway Southwestern Archæological Expedition in

1887–'88, by Sylvester Baxter (Salem, 1888). In addition to all this he has had the advantage of a personal knowledge of the southwestern country, its antiquities and its people, extending over a period of ten years. He has had an equally long intimate personal acquaintance with the director of the Hemenway Expedition. In the autumn of 1887 he had the rare good fortune to spend about a month with Mr. Cushing at Camp Hemenway, in the Salado Valley, while the excavations at Los Muertos were being carried on.

He might, therefore, had he so desired, have made of this introduction a more extensive and pretentious essay. This is intended, however, not as a contribution to American archæology, but merely for the convenience of the anthropologist who may desire to know something of the people to the description of whose osseous remains this work is chiefly devoted. The author has introduced only some of the more easily explained discoveries of the expedition, and he has made many statements without setting forth all the facts and arguments on which they are based. The reader must take some things for granted until Mr. Cushing's final report appears. In referring to the early Spanish writers and travelers the writer has been obliged to omit the proper bibliographical notes, for the reason that he had not access to their books at the time of writing.

In studying the crania and other bones described in the following pages, and in preparing this report, I must acknowledge my great indebtedness to the following gentlemen of the staff of the Army Medical Museum: To Dr. Jacob L. Wortman (who spent many months in the field collecting and preserving the bones), for assistance in preparing the sections on the teeth and hyoid bone; to Dr. D. S. Lamb, for assistance in preparing the section on the olecranon perforation; to Mr. Porter Tracy, for his labor in taking measurements and his help in many other ways, and to Dr. J. C. McConnell, for preparing the illustrations.

WASHINGTON MATTHEWS,
Surgeon, U. S. Army.

FORT WINGATE, NEW MEXICO,
September 1, 1890.

HUMAN BONES

OF

THE HEMENWAY COLLECTION.

PART I.

THE SERIES OF SALADO.

HUMAN BONES OF THE HEMENWAY COLLECTION.

PART I.—THE SERIES OF SALADO.

§ 1. CONDITION AND REPAIR OF BONES.

As we have stated in the introduction, the bones when found were in an advanced state of decay and exceedingly fragile; particularly was this the case at Los Muertos. The organic remains at Los Hornos, Los Guanacos, and Las Acequias were usually in better condition than at the first-named ruins, owing, probably, to the greater dryness or other more advantageous quality in the soil. At Las Acequias they were in the best condition of all. When carefully unearthed the bones, *in situ*, in the graves might seem in sound condition, but the slightest manipulation—a touch of the finger even—would cause them to crumble into dust. The bones of the upper face, the pelvis, and the epiphyses of the long bones were the most friable. Parts successfully unearthed, but not immediately conserved, if they escaped the despoiling foot of the mischievous visitor, would often disintegrate in a day or two from the effects of exposure to sun and wind. After a period of annoying experiences it became the custom to apply paraffin, shellac, or other preserving substance to the bones before their removal from the graves, or immediately after.

The skulls were nearly all obtained in a fragmentary condition; the fragments, carefully packed, were forwarded to the Army Medical Museum in Washington, and here a number were, with much labor, put together in such a manner that they might be measured and studied as entire skulls. The remaining fragments often gave us valuable points for anatomical study. In the work of restoration we had in many cases to use plaster of Paris to fill gaps or strengthen weak parts. Where the plaster was used superficially to replace thin scales from the outer table, measurements were, after due deliberation, sometimes taken from points on the plastered surface; but where the plaster had been thickly applied, had been used in restoring salient points, or had been employed to fill a gap in both tables of the bone, its presence was considered to preclude measurement. In a small number of skulls where we had, after restoration, reason to suspect the existence of post-mortem distortion, measurements were not made—not, at least, in the regions affected by the distortion. A great but unavoidable disadvantage in the use of the plaster was that it encroached on the cranial cavity and thus usually rendered the cubature of the latter impossible.

§ 2. THE MEASUREMENTS OF THE SKULLS.

In preparing this report we have kept two objects in view: First, that we might obtain material for our own study and comparison of this collection; and, second, that we might furnish to other investigators material for comparative study. In providing for the latter we have taken some measurements which we have not used as data for subsequent investigations, and we have not confined ourselves to the methods of any particular school or system.

For purposes of our own research we have employed chiefly the measurements of the French and English schools of anthropology as formulated in Dr. Paul Topinard's recent work,* because the literature of anthropology is richest in studies based on these measurements (Appendix A), and the opportunities for comparison with them is consequently most extensive.

Recognizing the fact that a great number of anthropologists throughout the world have signified their intention of employing the measurements proposed by certain German anthropologists, formulated in what is known as the Frankfort agreement (Appendix B), and hence,

*TOPINARD; Éléments d'Anthropologie Générale; Paris, 1885; chap. XXVII.

anticipating an extended use of this system in the future, we have taken many measurements according to this agreement.

Our decisions as to what to adopt and what to discard in different systems may appear occasionally somewhat arbitrary; but they have usually been made in accordance with certain rules which we have been constrained to adopt. We have not undertaken to sit in judgment on the general relative merits of any system. All the systems extant are the results of more thought and study than we have been able to devote to the subject of craniometry. We have accepted that which seemed best suited to the scope of our work and to the character and extent of the series to be studied. We have also had to take into consideration the limited time at our disposal.

Any measurement which we believed to be identical or practically the same in different systems we have taken but once and, in taking it, we have followed whichever rule seemed the most explicit or laid down the most definite landmarks. Thus, in taking such a short dimension as the interorbital width, where a small error may count for much, we have chosen for our landmark the definite dacryon as directed by Broca, instead of the less certain "inner border of the orbit," which the Frankfort agreement prescribes for us.

On some occasions we have discarded a dimension which had been made, or might be made, the basis of extensive and valuable study, for the simple reason that we did not regard the given directions as sufficiently explicit. While they might be clear to the scientist who wrote them, or to the student who saw him apply them, they were not clear to the reader who had nothing but the text to guide him. Thus we have taken no vertical measurements from the ophryon, because no one tells us in what plane the connecting line between the frontal ridges should lie. Two or more equally short lines between these ridges might, in some skulls, be described at some distance from one another on the median line. In other words, we might have two ophryons so far apart as to give materially different facial heights. We thought it better to be silent than to fill our pages with material which might prove worthless. Had we had unlimited space, time, and assistance we might have included such measurements, though not without comment.

Some measurements were forbidden by the character of the skulls. The bistephanic diameter was put aside because the temporal ridges in this series are indistinct, the indistinctness being due, possibly, to the general use of boiled vegetable food among the Saladoans and the consequent limited exercise of the temporal muscles. Moreover, the stephanion lies in a region especially liable to be broken, and frequently was broken in the series. We have substituted for this dimension the maximum frontal diameter of Emil Schmidt.* The upper incisors were so often missing that we neglected dimensions into which they entered. On the other hand, we took measurements from the metopion, which is a very uncertain guiding point on these skulls in consequence of the subdued character of the frontal bosses.

We felt a great temptation to present to the reader such opinions concerning all the measurements as we formed in the progress of our work, and to give our reasons in each case for adopting this or abandoning that method; but on mature reflection we felt that this would lead us beyond the proper scope of our work. In the more important cases, comments on the methods are given in connection with the discussions of particular dimensions or indices. In some instances we advanced far in the work of securing a dimension before we found practical reasons for abandoning it. In other cases we have taken a measurement on all the skulls of the series and compiled our tables and indices before we concluded to suppress our results. This we did, for instance, in the case of the horizontal and vertical measurements of the orbit.

We have, with some inconsistency, perhaps, adopted dimensions and followed rules of whose exactness we felt no less uncertain than we felt of some which we discarded. Such instances are, perhaps, to be classed among our arbitrary decisions. But we can partly atone for our errors, if such exist, by telling exactly what our own methods were. For instance, we have recorded measurements which have the superior border of the meatus auditorius for a guiding point, and we must confess that we know not where to locate this point with accuracy. The rule for our own

*Emil Schmidt: Catalog der im anatomischen Institut der Universität Leipzig aufgestellten craniologischen Sammlung; Archiv für Anthropologie, Braunschweig, 1887–'88, p. v.

guidance has been the contour of the processus auditorius or tympanic bone. Where this was complete in its upper portion, as it rarely is in man even in the lower races, we had no trouble in establishing our point. Where a good vestige of the upper part remained, not too far out of place, we were contented to take such vestige for our guide; but where a large segment of the bone was completely missing we joined the upper horns of the remaining portion by means of a pencil mark described as directly as possible from one horn to the other on the roof of the meatus and took the highest point of this arched line for our landmark. In leveling the skull for the German horizontal plane and in taking the auricular heights we felt less hesitancy in depending on this guiding point than in taking vertical arcs. Here it was most doubtful.

Table I is intended not only to answer the purposes of the present investigation, but possibly to serve as a model for future catalogues which may be issued by the Surgeon-General's Office. It has been designed with a view of economizing space and making reference easy. The peculiarities of its plan require little explanation. On the first page of the table and on its duplicate fly-leaf we have given a condensed description or indication of each measurement, index, or other item sufficient, we believe, for ready reference. In order to get each description within the space of one line we have rarely used the exact words of the original authors. For the measurement of the German anthropologists we have been especially compelled to reject the circumlocutions of the Frankfort agreement in describing guiding marks and have adopted instead the specific terminology of craniometric science. "Frankfort," in the table, denotes that the preceding rule is to be found, in substance, in the Frankfort agreement.* "Topinard" denotes that it is to be found in the work of this author already referred to. The number or letter which follows either of these names corresponds with that given to the item by the quoted authority; thus "Frankfort 1" refers to the first measurement of the Frankfort agreement. Feeling that our brief references to rules might often be insufficient for those who had not at hand copies of the oft-quoted Frankfort agreement and of the rules of Topinard, we have supplied these in Appendices A and B of this work.

§ 3. THE PICTURES OF THE SKULLS.

The outline tracings of the skulls shown in plates 1 to 54, inclusive, are reductions to half size, made by means of a pantograph from orthogonal or geometric drawings.

It seems proper that we should here describe the apparatus and the method in use for the past five years in the Army Medical Museum,† by which these orthogonal tracings were made, since both seem to differ in many respects from those in use elsewhere, as far as we may judge from published descriptions.

Fig. 23 represents the complete apparatus in use. It consists of a frame (*a*, *a*, *a*), inside of which is an open box (*b*) nearly filled with dry sharp sand (so arranged that it may be raised and lowered by means of a lever (*c*), a movable and adjustable mounted pin (*d*), an ordinary carpenter's or draughtsman's square, and a tracer of peculiar construction, which has been named the periglyph (*e*). The frame is surmounted by a movable plate of glass, thinly varnished on both sides to receive the tracing.

The periglyph is shown reduced in Fig. 24. It consists of a standard (*a*), a base (*b*) (both made preferably of vulcanite or hard wood), supported by two padded points (*c*), and by the sharp steel style (*d*), which makes the tracing; vertically above the extreme point of the style is a pin hole on an adjustable arm (*e*).

In other laboratories they use diopters, somewhat similar to this instrument in appearance, with which the outline is drawn by means of a pen or pencil held in hand. It needs but a single trial to convince one that our instrument, with its fixed steel tracer, is vastly more reliable and convenient. Of course the steel point would not trace on plain glass as the pen does; the thin coat of varnish renders the use of the style practicable.

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*Verständigung über ein gemeinsames craniometrisches Verfahren; Archiv für Anthropologie, Bd. XV, Braunschweig, 1884, pp. 1–8. (See Appendix B.)

†W. MATTHEWS: Apparatus for tracing orthogonal projections of the skull, in the United States Army Medical Museum. Journal of Anatomy and Physiology, vol. XXI, London, 1886–'87, pp. 42–45.

To ascertain if the pin hole is truly vertical to the apex of the style, we take sight through the former over the latter on some point of the object to be depicted under the glass, and wheel the instrument around—the point acting as the center—180 degrees. If the pin hole is vertical, the apex of the style will still cover the point on the object; if it is not vertical, we loosen the binding screw (*f*, Fig. 24) and adjust the arm (*e*).

The frame of our apparatus is 35^{cm} long, 28^{cm} broad, and 43^{cm} high; but some approximate size will do as well. The cross pieces which secure the upright supports are not placed at the top of the frame, but some 12^{cm} from it. There are two reasons for this: first, that no shadow may fall on the skull to obscure the vision of the operator, and second, that a horizontal surface may be afforded to support the mounted needle. The plane of the cross pieces must be perfectly parallel with that of the plate of glass.

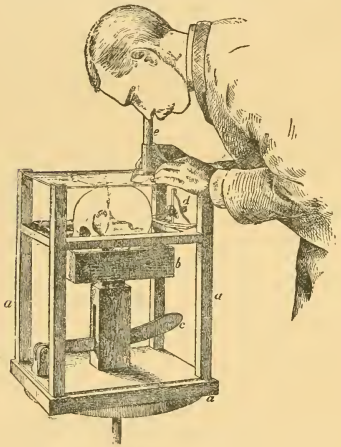

FIG. 23.—Apparatus for orthogonal tracings.

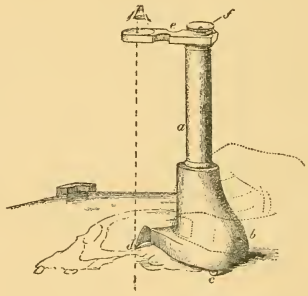

FIG. 24.—The periglyph.

The mounted needle (Fig. 23, *d*) alone is used when the datum plane lies horizontally, as in outlining the vertex, side, and base of the skull; but when the plane stands vertically, as in tracing the anterior and posterior views, the square is also employed to secure the desired adjustment.

For facilitating the adjustment of the skull accurately and readily in any position, and for maintaining it in position, we have found nothing to excel the sand box. The most elaborate mechanical contrivance could not, we imagine, answer the purpose better.

In this series, furthermore, the skulls were so fragile that they did not admit of the application of any craniphore that would produce the least pressure.

The following is the method of operation: Place the skull on the bed of sand, pressing it down until it stands firmly. By means of the lever raise the sand box until the skull is nearly or quite on a level with the slots in which the glass is to fit. Orient the skull in the sand with the aid of the mounted needle, or the square, as the case may require; put the varnished glass in place; by means of the periglyph make the desired tracing; take off the glass. If a positive picture is desired, trace over the scratched drawing on the reversed side of the glass with ink. When the ink is dry, proceed to make the imprint. Lay unglazed paper on the inked figure and press it firmly down with one hand to prevent slipping; raise a small portion of the paper with the other hand; breathe in one spot upon the ink sufficiently to moisten it; replace the paper and rub it

briskly over the moistened surface with the thumb nail. Treat the entire figure in this way. If a reverse picture is wanted, which is usually the case when a finished drawing is to be prepared for engraving, ink the scratched line and take the imprint therefrom.

If it is desired to prove the correctness of a positive picture, wash away the ink from which the imprint has been made, ink the scratched drawing and place it right side up over the positive on the paper. The two should correspond. In no instance where we have made this test have we found the slightest error.

We have used an ordinary black ink, and have been able to take three good impressions from one drawing. If it were desirable to take a large number of copies, other inks could be found to accomplish the purpose.

Dr. Paul Topinard tell us* that with Broca's stereograph the five views of the skull may be made in an hour. It takes nearly twice that time to do the same with our contrivance, operating with proper care; but as a partial compensation for this we have a drawing which furnishes many duplicates.

No special skill or lightness of hand is required with our apparatus; any person possessed of ordinary intelligence and eyesight can use it successfully at the first trial. It is not complicated; it requires no highly skilled workman to construct it; it may be made by any carpenter and its cost is insignificant.

Even the periglyph may be made by any handy individual with an ordinary pocket knife. We have two periglyphs, one manufactured of metal by a practical model-maker, the other rudely whittled out of wood by a medical gentleman connected with the Museum; both are perfectly accurate, but the latter is the more easily handled and the favorite instrument.

Several outlines may, without confusion, be drawn on the same varnished surface. The varnish should be of such a character that when dry it becomes crisp and brittle, breaking up in the course of the stylus—not dragging after the instrument and clogging it. Of many mixtures tried that known in the trade as Berry Brothers' (Detroit) hard-oil finish, diluted with one-third turpentine, gave the best results.

In making all but six of these tracings we adjusted the skulls on the German horizontal plane, or plane of the Frankfort agreement, partly for the reason that with the sand box we could find this plane more readily than we could find the alveolo-condylean plane. But for purposes of comparison we sketched the *norma verticalis* parallel with the alveolo-condylean plane in six specimens, the type skull and five which approximated the type. The reduced tracings are shown in plate 51.

The five views of the type skull† (Pls. 55–59, incl.) were made on the basis of elaborate orthogonal tracings, the shading being added by the artist from nature. They are natural size. It is greatly to be regretted that the nasal bones in the type skull were broken, and that we were obliged to make a plaster restoration. The shape of the nasal aperture is only approximate.

There were but few skulls in this series in which all the points of the German horizontal plane or any other horizontal plane could be found to coincide with a true horizon, while the sagittal plane was perfectly vertical to such horizon. The variance was most marked at the upper borders of the auditory meatuses. In order to approximate uniformity we always aligned our facial guiding marks, not with the upper margin of the right meatus, but with that of the left, the side on which the *norma lateralis* was taken.

The views of the lower jaws in plates 52, 53, and 54 were taken with the same apparatus and by the same method as were those of the skulls, and similarly reduced by the pantograph. When each was drawn the plate of glass on which the tracing was made was parallel to the plane on which the lower margin of the jaw rested at equilibrium.

Areas in the drawings marked with parallel straight lines show where there are holes in the skulls, neither bone nor plaster being present. Dotted areas indicate plaster restorations—all such repairs, whether deep or superficial, being thus shown.

Op. cit., p. 863. †For description see § 14.

§ 4. SEX.

In twenty-one cases the skulls are accompanied by enough of the remaining bones to let the sex be stated with considerable confidence. These twenty-one skulls are the following:

Males: Nos. H. 6, H. 7, H. 14, H. 18, H. 19, H. 24, H. 25, H. 26, H. 32, H. 34, H. 41—total, 11.

Females: H. 1, H. 5, H. 8, H. 10, H. 15, H. 21, H. 36, H. 39, H. 45, H. 57—total, 10.

These groups appear to be so scattered through the various ordinations that it can not with safety be said that the sexes are distinguished from each other by any metrical characteristics.

Although it is universally attempted to distingnish the sex of, say, four skulls in five, we do not consider it possible, in the present case at least, to do so; for, firstly, the number of known sex is so small that it is not possible to say that there is a constant sexual difference in any particular dimensional relation; secondly, there is apparently no constant difference of anatomical detail, such as prominent processes, "strong marking," or the like. The sex of H. 40, the type skull, can not be certainly stated, but, very reservedly, of course, we may suggest the probability of its being female. In this connection it is interesting to note that H. 7 and H. 25, males, also closely represent the type and closely resemble one another.

§ 5. PATHOLOGY.

Of the Salado collection about 69 sets of bones, representing each a complete individual skeleton, or the majority of bones of one individual, have come to us; but, as these sets are sometimes mixed with bones which do not belong to them, and as there are many miscellaneous bones in the collection, percentages of pathological formations must in some cases be only approximate. The collection shows some interesting anomalies, diseases, and injuries.

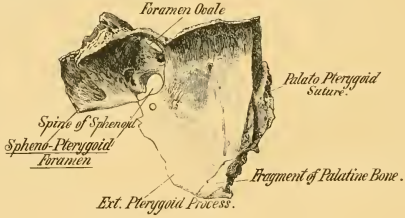

FIG. 25.—Fragment of skull, showing spheno-pterygoid foramen.

Anomalies.—The more important anomalies, those supposed to be of anthropological significance, are discussed more fully elsewhere, under separate headings. Some of those of minor importance will be considered here. In one case (fragment) the occipital bone showed two small, smooth, rounded condyloid prominences close to each other at the anterior part of the foramen magnum. The condyles proper were somewhat broken, but appeared to be smaller than usual, though normally located.

In one case (H. 21, Pl. 21) the foramen magnum was of unusual size. At least the portion of its border, the posterior half, which remained, indicated that the foramen was very large. The basilar portion of the occipital bone was missing.

The spheno-pterygoid foramen, complete or incomplete, was not found in any of the restored skulls; but in one small fragment a complete foramen was found, where the two processes which formed its boundaries touched but were not coössified (Fig. 25).

In H. 33 the occipital bone showed behind the right condyle, from which it was separated by a narrow groove, a small, smooth surface which articulated with a corresponding small, smooth surface on the atlas, behind the usual kidney-shaped articular surface. In the case of the atlas also there was an absence of the spinous process and of a small part of the posterior arch on each side, leaving a gap in the bone. There was no sign of inflammatory action.

In several instances the groove on the atlas for the suboccipital artery and nerve was converted into a foramen more or less complete, sometimes on both sides in the same subject. In H. 25 there are very complete foramina on both sides. In a number of cases the vertebral foramen was subdivided into two openings, and sometimes it was much smaller on one side than on the other.

Among the vertebræ there were five instances of what might have been congenital union; in two the occipital bone was united with the atlas; in two others the axis was united with the third cervical vertebra, and in one, two adjoining dorsal vertebræ were soldered together. The lines of union in these cases were even and smooth and there were no exostotic growths adjacent to suggest the existence of inflammation. In one other case of union of the axis and third cervical vertebra, more doubtfully of congental origin, there was partial destruction of the posterior arch of the axis, apparently due to suppuration.

There were four cases of union of the first and second pieces of the sternum, showing the usual incompleteness by the small cavity in the articulation. There were also some cases of fissure of the lower part of the sternum, and the shape of the ossified portion of the ensiform appendix varied as usual.

One rib was bifurcated anteriorly.

The tibiæ and fibulæ on both sides in H. 90 exhibited a marked uniform symmetrical anterior curvature. The index of the right tibia, as shown in Table LXXIV, was 53.03, a very low index, yet exceeded in this respect by several of the series. The index of the left tibia was not computed, as the bone was so split that it was feared the normal dimensions could not be obtained. These were the only leg bones that showed this curvature to any noteworthy degree. They were better entitled to the name of saber bones than any in the series. There was no certain sign of inflammation or degeneration in these bones. The skeleton unfortunately was quite incomplete, but what remained showed the following lesions: A healed fracture of the outer third of the right clavicle; small exostoses on the articular surfaces of the condyles of the lower jaw; bony growths on the sites of many tendinous insertions; a few of the vertebral bodies were very friable and a large osteophyte bound them together anteriorly. This is the only case which suggested the possibility of rickets, but the symmetry of the curvature disposes one to doubt that this disease exis.ed.

Still it is possible that the case comes under the class described by Agnew* as "mild form of rickets."

Injuries.—There were some specimens showing the healing of fractures, three of the clavicle and one of the tibia; the latter had healed with marked deformity. Recent fractures could not of course be recognized because of the general fragmentary character of the bones.

In one case, where unfortunately most of the vertebræ were absent, one of the dorsal vertebræ, apparently the eleventh, showed the condition somewhat like that seen in cheesy degeneration and caries of the vertebral bodies. The body of the bone was shaped like a truncated wedge (*vide infra*). In the same case three ribs, apparently the sixth, seventh, and eighth, right side, showed posteriorly from the head to the angle a rough surface with exostotic growths, as if the ribs had formed the wall of an abscess. There was also an impacted fracture of the neck of the right femur, and the right ulna and both fibulæ showed an uneven surface that might possibly have resulted from a contusion with consequent inflammation. Altogether I regard the condition as one general injury, probably from a fall on the right side.

There was one case of fracture of rib with good union and no deformity except a slight overlapping.

There was one case of anchylosis of astragalus and *os calcis*, and another of the second metatarsal and middle cuneiform bones, both probably traumatic.

Disease.—In about one-third of the cases periosteal fringes of new bone were found along the edges of the bodies, and sometimes of the laminæ of the vertebræ. In view of the incompleteness of the individual sets, it is impossible to state with any accuracy the relative frequency with which the disease occurred in the different regions. Apparently it affected most frequently the lumbar region, next the dorsal, then the cervical, and least of all the sacral. In two cases only there

*AGNEW: Principles and Practice of Surgery, Philadelphia, 1878; Vol. I. p. 1032.

were actual bridges of bone, and these connected adjoining lumbar vertebræ. These exostotic growths resembled those seen in the bones of individuals who have worked hard and been exposed to cold and wet, those often found in the bones of the dissecting-room subjects. The condition may be termed "rheumatoid." It is worthy of observation that the vertebræ were much more frequently affected than the other bones of the skeleton.

The frequency of this rheumatoid condition in the people represented by these bones may seem rather surprising in view of the mild character of the climate at the present day, which is probably similar to what it was in their time; but, granting the existence of this condition, it is easy to understand its predominance along the spine. The Saladoans were a hard-working people, whose labor was of such a character as to cause much bending of the back, to make them perspire freely, and to subject them to sudden changes of temperature while perspiration was active. In short, they lived in many respects under conditions similar to those of our own laboring classes, and we need not wonder that they suffered from similar maladies of the vertebral column.

There was one case of antero-posterior curvature of the spine in an adult which merits special description. In the dorsal region a number of adjoining vertebræ had their bodies symmetrically and bilaterally diminished from behind forwards; they had the shape of a truncated wedge with its base posterior. No distinct evidence of caries could be discovered, as in Potts disease, but the friable and injured condition of the bones did not permit us to announce a positive opinion on this point. The change in shape seemed more probably due to an interstitial absorbtion than to caries. We should hesitate to say that it was a case of tubercular degeneration; there was no satisfactory evidence of the existence of such a condition in any bone in the collection. There were many fringes of new bone along the bodies of the diseased vertebræ, and there was firm coössification of adjoining bones at the left sacro-iliac synchondrosis. There may be other skeletons in this series which had similar lesions, but the loss or destruction of some of the vertebræ forbid us to speak with certainty. We have in the general collection of the Museum a skeleton from Alaska showing a condition similar to that described, and we will anticipate Part II of this work by saying that we have another such skeleton in the series of Cibola.

A disease exists in Zuñi which Mr. Cushing, freely translating the Zuñi name, calls the "warps." It consists of a gradually increasing, symmetrical, antero-posterior curvature of the spine, which, when it reaches completion, after years of progress, brings the knees in close proximity to the chest and renders walking impossible. The patient is obliged to go around on short crutches and is reduced to a helpless condition, his only useful occupation being the knitting of stockings. The disease is not accompanied by abscesses or sinuses, and the general health of the afflicted person is not seriously impaired. It is said that on the first appearance of the malady, if the patient will permit himself to be tied night and day to a straight board, he may avoid the worst consequences; but either this is not an infallible remedy or there are some who have not the fortitude to submit to it, for the writer has seen at least half a dozen sufferers in the pueblo of Zuñi, all adults and mostly males. The connection, if any exists, between this disease and the spinal curvature of the Saladoans and Cibolans, referred to above, is worthy of investigation.

In several cases the conditions suggested the possibility, but by no means demonstrated the certainty, of syphilitic disease. Thus in one there was irregular nodular hypertrophy of the shafts of both tibiæ, more especially the right, of the lower part of the right fibula, and of the shafts of both ulnæ, while the sternal ends of the first ribs showed exostotic growths. In some cases there was hypertrophy of the tibial shafts without any other evidence of disease.

The fragmentary and worn conditions of the skulls interfere with the recognition of disease and injury. There were, however, abundant evidences of alveolar abscess, more especially in the lower jaw; and in a few cases the alveolar wall was perforated. In one case the left lower incisor and part of the alveolus were absent, probably from abscess or injury, but in this situation giving a very peculiar appearance to the jaw.

In 2 or 3 cases the eminentia articularis was eroded on one side, and the corresponding condyle was also largely destroyed. It seemed to be rather the result of atrophy than inflammation.

The lesions of the jaws and teeth are futher considered in the section on teeth.

§ 6. THE CEPHALIC INDEX.

The most notable feature of this collection of skulls—the feature which at once attracts the attention of the observer—is the antero-posterior shortening. Excluding those which bear undoubted evidence of post-mortem distortion, the longest skull (H. 23, Table II) in 48, whose indices are obtainable has a cephalic index, computed from the measurements prescribed by Broca, of only 78.40, which is within the limits of mesaticephaly. There are but 4 skulls which are longer than sub-brachycephalic, and but 7 which are not truly brachycephalic. The shortest skull has an index of 97.97. The mean of all the 48 indices is 88.47, which is an extreme grade of brachycephaly—the brachystocephaly of Huxley.

§ 7. OCCIPITAL FLATTENING.

Associated with this shortening of the skull we find more or less depression or absolute flattening of the occiput. In the most marked cases we can not doubt that this flattening is artificially, although not necessarily intentionally, produced. Between the very flat occiputs and those which, though not prominent, are quite rounded there are many degrees of variation and the areas of the flattening are of various sizes from those that comprise the entire occipital region, and show definite boundaries to those which might easily escape the attention of the student, or might, disassociated from the rest of the group, be regarded as normal peculiarities.

The occipital flattening here referred to, must be carefully distinguished from that produced intentionally by the ancient Peruvians, by the Flatheads of our Northwest coast, and by other races. In the latter there is an anterior counter-flattening produced by the pressure applied to the forehead; in the former there is no frontal flattening.

The cause of this flattening of the occiput, whatever it may be, would seem to be the cause, under modifying circumstances, of the brachycephaly in general, whether absolute flattening exists or not. Such flattening has been observed among various American races, both extinct and extant, and is by some attributed to the use of a hard board for the back of the basket, case, or cradle in which the baby is carried.* There is no doubt in our mind that this is the prime cause of the flattening and the brachycephaly in the skulls of this series. The variations may depend on the different degrees of hardness of the skulls or on the character and size of the pad or pillow used, or on both.

In 46 cases where the occipital depression notably affects the sagittal circumference we have it variously distributed. This distribution may be broadly divided into three groups. These are illustrated in Figs. 26, 27, and 28, which consist of superimposed outlines adjusted on the bregma, the superior margin of the meatus auditorius, and German horizontal plane.

In the first group (A) the depression, whether there is actual flattening or not, is pretty evenly distributed over the entire posterior portion of the sagittal curve from the opisthion to the obelion. This may be called total posterior depression. (See Fig. 26.)

In the second group (B) the depression is mostly from the inion to the obelion; that portion of the median line below the inion seeming to be little affected, this we may designate as depression above the inion. (See Fig. 27.)

In the third group (C) the flattening or depression is mostly above the lambda, the median line below that point being nearly or quite normal. (See Fig. 28.)

As the outlines of all the skulls which satisfactorily illustrate the sagittal depression have been used in composing Figs. 26, 27, and 28, it will be seen that the first group is much the most numerous, there being 14 skulls of this group to 6 of the second and 4 of the third.

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* Carr, Lucien: Observations on the Crania from the stone graves in Tennessee. Eleventh Annual Report of the Peabody Museum of Archæology and Ethnology. Cambridge, Mass., 1878, pp. 361–384. Shufeldt: A Navajo Skull. Journal of Anatomy and Physiology, Vol. xx, London, 1885–'86, pp. 426–429. Shufeldt: A Skull of a Navajo Child. Journal of Anatomy and Physiology. Vol. xxi, London, 1886, pp. 66 *et seq.* Shufeldt: Contributions to the Comparative Craniology of the North American Indians. Journal of Anatomy and Physiology, Vol. xxi, London, 1887, pp. 525 *et seq.* Mason, O. T.: Indian Cradles and Head Flattening. Science, Vol. ix, No. 229, New York, June 24, 1897, pp. 617 *et seq.*

These groups are believed to be not devoid of significance, and will be made the basis of future comparative study of American races. It has been already found, for instance, that in skulls dug from American mounds, where occipital flattening is often encountered, that total posterior flattening (Group A) is much the rarest form. In 68 mound skulls, with sagittal depression, the groups are distributed as follows: Group A, 7; Group B, 51; Group C, 10. It may be, too, that our future studies will compel us to establish another class, in which the depression is below the lambda.

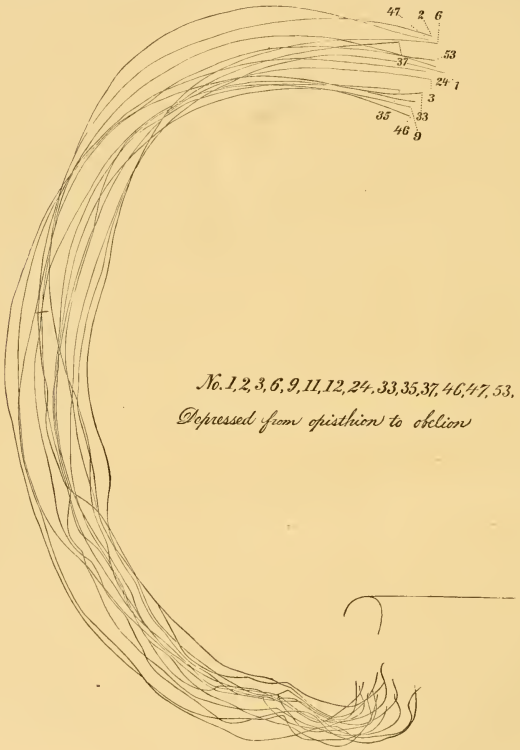

FIG. 26.—Occipital depression. Group A.

Besides these sagittal variations in depression, we have different forms and degrees of lateral depression, *i. e.*, the depression, instead of having its center on the median line, has it more or less to one side. This character naturally divides itself into two groups—right and left. In forming these groups we have depended upon a mere inspection of the skull and not upon measurements, only a skull which had an obvious lateral deformity being included in either group.

These lateral deformities are not to be profitably considered under the head of plagiocephaly as defined by Broca. According to this author a certain depression of the frontal bone on one side accompanies a depression of the parietal on the opposite side in the condition to which he applies this name. While in this collection there are some true plagiocephalic skulls, the majority having the posterior lateral flattening have not the accompanying frontal flattening. Hence they have been all first studied together with regard to the posterior flattening only. Of a skull thus

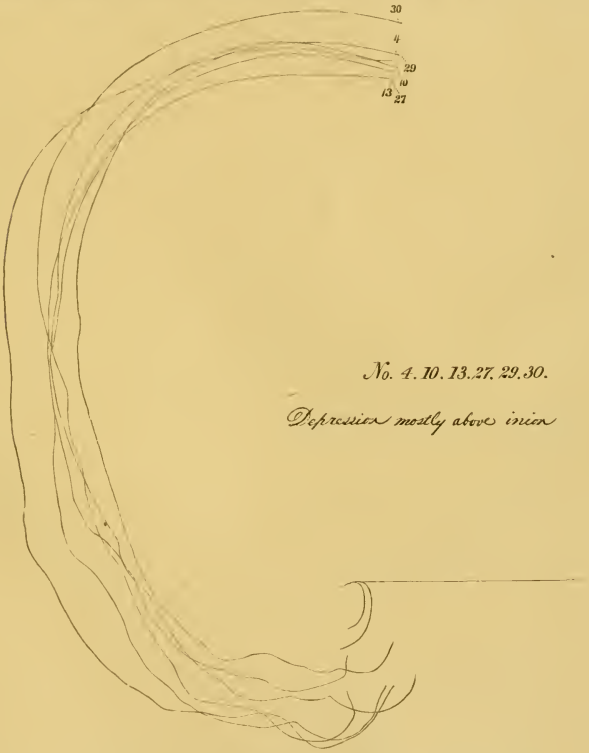

FIG. 27.—Occipital depression. Group B.

flattened on the left side we say it has left posterior flattening, although it may have right plagiocephaly, and of a skull thus flattened on the right side we say it has right posterior flattening, although it may have left plagiocephaly. In short we study this deformity first without regard to plagiocephaly.

Out of 28 skulls showing the lateral posterior depression, 19 are flattened on the left side and 9 on the right. These deformities are illustrated in Figs. 29 and 30, which represent superimposed outlines adjusted on the median line and the maximum occipital point.

Thus we see that the skulls flattened on the left side are twice as many as those flattened on the right. Right-handed women carry the child usually on the left arm, and therefore suckle it mostly at the left breast,* and right-handed people predominate greatly over the left-handed in all

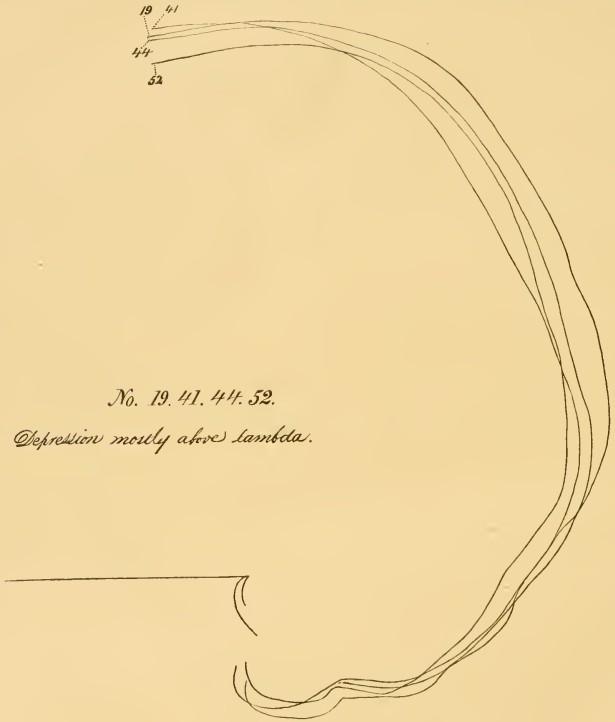

FIG. 28.—Occipital depression. Group C.

races. When lying on the hard cradle-board, then, the heads of the great majority of infants should more frequently incline to the right than to the left, and should therefore, we would suppose, be more likely to become flattened on the right side. In our mound skulls the flattening is much more frequent on the right side than on the left, in the proportion of 62 right to 39 left in 101 skulls in which lateral posterior flattening is found.

* JOHN A. WYETH. "Anatomical Reasons for Dextral Preference in Man." Annals of Anatomical and Surgical Society, Brooklyn, N. Y., Vol. II, 1880, p. 129.

One peculiar effect of the occipital flattening is observed in the horizontal circumference. In certain of these skulls (II. 4, II. 10, and II. 47) a curious difficulty has been encountered concerning the horizontal circumference. It is prescribed that this circumference, which is supposd to be the maximum, be taken on a line passing above the supraciliary ridges and through the maximum occipital point; thus the posterior segment of the circumference encircles, so to speak, the posterior end of the maximum length. But in these skulls the line indicating the greatest circumference passes high up toward the obelion, and is drawn through so high a plane of the skull that the greater breadth of the skull at points below that plane more than compensates for its slightly less length; therefore the maximum circumference does not lie in the same plane as the maximum length.

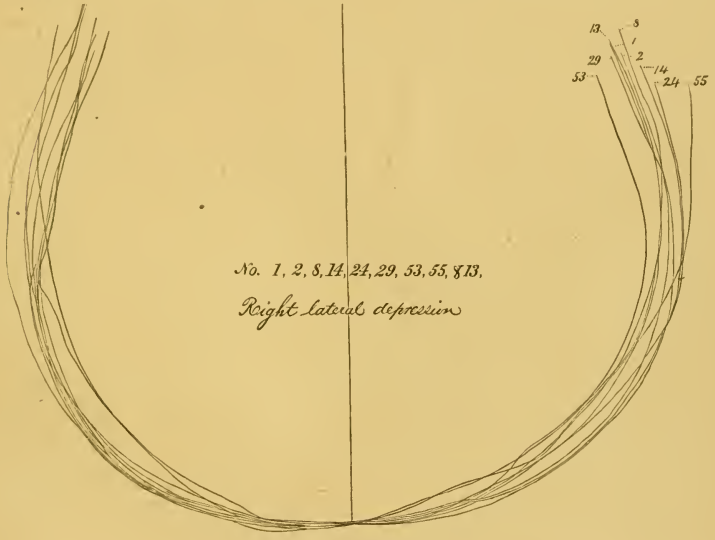

FIG. 29.—Occipital depression, right lateral.

Again; suppose that we take a skull of any ordinary shape and paint a line around it in the horizontal plane of its greatest length. If we then look downward upon the vertex of the skull we shall hardly see the line at all, because it corresponds so nearly to the outline of the skull in *norma verticalis;* but if we take one of the deformed skulls in question and paint a line correspondingly related to the maximum length and then look down upon the skull, we shall see painted upon it an ovoid figure which coincides with the outline of the skull only at its posterior extremity. This is owing to the fact that the most protuberant regions of the cranial parietes are situated much below the horizontal plane of the greatest length.

In these cases both the maximum circumference and the circumference around the maximum occipital point have been recorded, although it has been a matter of great difficulty to determine exactly the maximum circumference, and a series of measurements of the same made at long intervals of time would probably show considerable variation.

§ 8. APPARENTLY NORMAL SKULLS.

There are 16 skulls which, if never seen in connection with the rest of the collection, might readily be regarded as normal skulls. Taken by themselves, the fact that they are deformed is not obvious; studied along with the rest of the group, where there is every gradation from the most unquestionably flattened to the apparently normal, the observer has no doubt that the causes which operated in distorting the former class have had their effect too in shaping the latter, and he feels uncertain where, in any shortened skulls, he is to draw the dividing line between the normal and the abnormal. To what extent do the pillow and cradle of civilization affect the skull? In our great collection of Indian crania, those which are the longest, without obvious artificial deformity, and those which have the best developed occipital shells belong to tribes which

FIG. 30.—Occipital depression, left lateral.

use no cradle-boards or baby baskets; but carry their children in soft bundles, on the back, in blankets or in frames which present a flexible surface of stretched cloth or buckskin to the occiput of the infant.

It is evident (see Tables IV and V) that these apparently normal skulls partake fully of the brachycephaly of the whole group. They represent neither the longest nor the shortest of the entire series; their extremes being 78.40 and 94.66, and their average cranial index (86.94) is but little lower than the average of all (88.47).

Many craniometricians advise that the deformed skulls like most in this collection should not have their cranial measurements taken or placed on record for comparison. Such advice has not been followed here. All that do not show decided post-mortem distortion have been measured. This has been done because of the uncertainty referred to above in distinguishing between the normal

and the abnormal, because the occipital distortion is found in the skulls of so many of our American races, and because it is felt that its careful study by measurement may eventually prove of great value in comparing the races. In some cases, however, separate tables have been arranged for the apparently normal skulls, which are designated as follows: Numbers H. 7, H. 12, H. 15, H. 18, H. 19, H. 21, H. 23, H. 25, H. 26, H. 31, H. 36, H. 39, H. 40, H. 44, H. 54, H. 57. (See Tables IV and V).

§ 9. POSITION OF MAXIMUM OCCIPITAL POINT.

A feature, probably the effect of occipital distortion, which is usual in these skulls is the elevated position of the maximum occipital point. In 50 specimens in which the position of the lambda may be determined, we find that the maximum occipital point lies above it in 10, and at it or less than 5^{mm} below it in 10 more. In other words, the maximum occipital point lies without the occipital bone in 20 per cent of the specimens and is barely included in the latter in another 20 per cent. In 3 of the former 10 skulls the point is seen in the region of the obelion. In the remaining 30 skulls, while it is found on the occipital bone, it is usually found high on it. In only 5 cases (10 per cent of all) does the point appear in the region of that usually ill-defined locality, in these skulls, the inion.

§ 10. THE LENGTH-BREADTH INDEX.

The equality in this collection of the cephalic index of Broca to the length-breadth index of the Frankfort agreement is remarkable and is due no doubt to the occipital flattening. The maximum occipital point being unusually elevated by reason of the flattening (§ 9), it often coincides, or nearly coincides, with the posterior extremity of the German horizontal length, thus approximating the only factors of these two indices that differ. In 13* out of 47 cases these two indices are exactly equal to one another; in one-half† of the 34 remaining cases the indices differ less than one unit. According to this index the longest skull is again H. 23, and it is one of those skulls in which both indices are alike. H. 46 is again the shortest skull, but its horizontal length being shorter than its greatest length, we have the higher length-breadth index of 99.31. According to the "agreement" concerning this index, 3 skulls only are mesocephalic, 8 are brachycephalic, and 36 are hyperbrachycephalic. The average, closely approximating that of the analogous vertico-transverse index, is 88.75, an extreme grade of brachycephaly.

In 10 instances‡ we have the confusing record of a vertico-transverse index higher than a length-breadth index. This involves the paradox of a length greater than the maximum length. A reference to measurements 6 and 7, in Table I, will show, furthermore, that such is our actual entry in the cases where footnotes are referred to. This apparent inconsistency arises from the following conditions: First, the occiputs of these skulls are so distorted that one side of them projects posteriorly beyond not only the other side but beyond any point in the posterior part of the sagittal plane, so that the profile of the skull does not correspond in outline to a section in the sagittal plane. Hence, second, the longest dimension parallel to the horizontal plane is not in the sagittal plane. We do not, however, measure directly from the glabella to the most prominent side of the occiput, which would give us an oblique measurement, but by means of the vertical plates of Spengel's craniometer we measure that which is a line parallel to the sagittal plane but lying to one side of it. Imagining this line to be projected upon the sagittal plane, we reckon our indices according to the accepted formula. We might have so modified the results or the modes of measurement as to remove this discrepancy from the record, but we considered it more candid as well as more scientific to give the results as originally determined.

§ 11. THE VERTICAL INDICES.

The occipital depression referred to not only directly shortens the antero-posterior diameter, but increases the height and width of the skulls actually as well as comparatively. As a consequence, not only is the cephalic index very large throughout the group, but the vertical indices are correspondingly exaggerated.

* Nos. H. 3, H. 5, H. 6, H. 7, H. 11, H. 12, H. 14, H. 18, H. 23, H. 32, H. 44, H. 52, H. 55.

† Nos. H. 9, H. 13, H. 15, H. 16, H. 21, H. 25, H. 26, H. 27, H. 34, H. 35, H. 36, H. 37, H. 41, H. 42, H. 50, H. 53, H. 56.

‡ Nos. H. 9, H. 19, H. 21, H. 25, H. 28, H. 40, H. 42, H. 53, H. 56, H. 57.

The vertico-longitudinal index was obtained in 40 skulls (Table VIII). Its extremes in adult skulls are 78.79 and 97.29. We have a child's skull, however, which has an index of but 77.70, and it is well to observe that the maximum index (skull H. 32) is far removed from the rest of the group, the next greatest being 92.56. The average of 39 adult skulls is 83.24.

Our lowest index is within the limit of high skulls as given by any known authority. Sir William Turner applies the term acrocephalic to all crania with an index of 77 or above.*

In the list of the vertico-transverse index (which may be computed in 39 skulls) the lowest is 84.82, the highest is 105.88. This belongs to the same skull, which has the highest length-height index, namely, H. 32. In respect to the index now under consideration, H. 32 is not so far removed from the rest of the group as it is in the length-height index, as will be seen in Table XIV, where the highest five indices are: 105.88, 104.47, 103.62, 102.27, and 101.39.

In 36 skulls both the vertico-longitudinal and the vertico-transverse indices were ascertained, and from those we were able to determine the *mixed index of height* of Topinard.† Of these 36 skulls the average vertico-longitudinal index is 85.40, the average vertico-transverse index 96.49, and the mixed index 90.94. (See Table XVII.)

A casual glance at the above figures might lead to the conclusion that the pressure on the occipital tended more to increase the width than the height of the skull, but such is probably not the case. The transverse measurement is taken wherever the maximum width falls; the height measurement is taken from basion to bregma, and the latter is in no case the highest point on the sagittal suture in this group—it rarely approximates the highest point. If a series of vertical measurements were taken from either the German horizontal plane or the alveolo-condylean plane extended, the most distant point of the sagittal suture would usually be found posterior both to the bregma and the vertex of Broca, and often nearer to the obelion than to either. Thus it probably is that the vertico-transverse index is the greater of the vertical indices.

§ 12. THE PLANE OF THE *FORAMEN MAGNUM* OR OPISTHIO-BASILAR PLANE.

In 29 skulls, where the landmarks were intact, we have determined the degree of inclination of this plane according to the three methods usually employed, *i. e.*, we have taken the angle of Daubenton, the occipital angle of Broca, and the basilar angle of Broca. Tables XVIII–XXIII give the results of our measurements, recording in no case less than half a degree.

We are told‡ of the angle of Daubenton that its lowest recorded expression is — 16 in an Auvergnean, and its highest + 19 in a Hottentot. In the Hemenway collection we have no minus quantities for this angle; our lowest is + 4° 30′, while our highest far exceeds this exemplary Hottentot, being + 23°. The highest average we have seen mentioned is + 9.34 in Nubians, but the average of the Saladoans is 13.30.

The occipital and basilar angles of Broca are, of course, correspondingly exaggerated in our series, the mean and extreme of the former being respectively 24° 15′ and 35°, and of the latter 32° 15′ and 46° 30′ (Tables XX and XXII). The mean of the Nubian basilar angle is 26° 32′.

The opisthio-basilar line is very approximately a continuation of the alveolo-basilar line in skulls H. 10 and H. 23, whose angle is, of Daubenton, 18° 30′. A straightedge applied to the median line at the base may be made to almost touch at the same time the alveolar point, the basion, and the opisthion. We may say, then, that the plane of the foramen magnum in these two cases looks directly downward. In skulls H. 18, H. 24, and H. 25, whose angles exceed 18° 30′ the plane looks downward and backward. In the rest of the series it looks downward and more or less forward.

If the inclination of the plane of the foramen magnum were accepted as a measure of evolution, the Saladoans would stand at the bottom of the human scale. We are inclined either to regard their peculiarity in this respect as additional evidence in support of Topinard's opinion that the

* TURNER: The zoölogy of the voyage of H. M. S. *Challenger*, Part XXIX, Report on the Human Skeletons—The Crania. London, 1884, p. 5.

† *Op. cit.*, p. 683.

‡ BROCA: Sur l'angle orbito-occipital, Revue d'Anthropologie, t. 6, Paris, 1877, p. 394.

character which the angle of Daubenton expresses is not of "a serial anthropological character,"* or to think that the pressure on the occiput, before referred to (§ 7), has influenced the position of the *foramen magnum*. It is not, however, in the most flattened skulls that we find the highest angles.

§ 13. CAPACITY OF CRANIAL CAVITY.

We have already stated that it was found necessary to repair the greater part of the skulls of this series with plaster of Paris. This often so encroached on the cranial cavity as to make it impossible to determine the cubic capacity of the latter. In 8 skulls only were we able to find the cubic contents of the brain case, and these were so friable that neither water nor shot could be used in them. The measurements were made by means of mustard seed; not according to any method previously laid down for the use of this seed, but by a system of our own, approximating closely to Broca's method for the use of shot.

The plan is as follows: Use the funnels, rammer, and tin vessels as for shot cubature. Use the 2,000-centimeter graduated glass with its leveling rammer. First, lay the skull on its vertex. Pour in rapidly a liter of seed through the wide-necked funnel. Pour in, in same way, so much more seed that when the skull is set upon its face and frontal bone the seed will form nearly a level across the skull from foramen to near middle of sagittal suture. Second, insert large end of rammer into foramen, gently press seed toward frontal region, with side of rammer in such a way as to level the surface of whatever quantity of seed is in the skull. Third, fill small-necked funnel with seed; hold it in left hand with finger over its mouth. The skull, as has been said, is standing on its frontal region. Grasp occiput with right hand and slowly incline the skull into the vertex-downward position as before, while running in seed through small funnel. During this operation the seed will overflow the foramen three or four times; when it does so, thrust seed into skull with forefinger of right hand; but as soon as pressure is felt, stop pressing. When the finger can no longer be introduced into the foramen without feeling decided resistance, and the skull has been completely lowered into vertex-down position, let the seed form a heap over foramen, press this heap vigorously into foramen with right thumb, and add seed to level foramen. Fourth, cover foramen with cotton wad and shake stray seeds from surface of skull. Fifth, empty contents of skull into double liter tin. Pour all the seed as rapidly as may be from double liter into 2,000 c. c. eprouvette, using no funnel. Bring leveling rammer of eprouvette down firmly, but not violently, on seed to level it. Sixth, read the eprouvette.

That the above method gives good results which fairly admit of comparison with results obtained by shot, there is little doubt, for the following reasons: We made according to this plan five measurements on one of Professor Ranke's bronze skulls, which was presented by the inventor to our Museum. The capacity of this bronze cast, as ascertained by ourselves, with water, atmosphere, and all accessories at a temperature of 60° F., was 1,240 c. c. (The bronze is marked 1,250 c. c., but this seems to be an error.) Our measurements of the capacity of this object with mustard seed ranged from 1,230 + to 1,250—, with an average of 1,242. We made measurements on this plan of some natural skulls in our collection which had been repeatedly measured with water and with shot according to Broca's system, and, applying three or more measurements to each skull, we arrived at results more uniform than those obtained with the artificial skull of Ranke. The mustard seed gave as a rule higher figures than those obtained by shot or water, but the average excess was less than 1 per cent.

Of the eight skulls measured four were male, two female, and two of doubtful sex. With such a small series we have not considered it proper to study the capacity of the sexes separately. The highest capacity belongs to a female skull, the lowest capacity to a skull of unknown sex. All the specimens pertain to subjects of mature age, and none are senile.

The highest two capacities are, in cubic centimeters, 1,530 and 1,510, which according to Broca's nomenclature† belong to skulls of the medium or ordinary class. Four capacities, viz, 1,390, 1,330, 1,310 and 1,170, belong to his class of small (*petite*) skulls. The remaining two capacities, 1,150 and 1,120, belong to the microcephali or lowest class. The average capacity is only 1,313. It might be urged that since our series of capacities represent such a small proportion

* *Op. cit.*, p. 814. † TOPINARD, *op. cit.*, p. 610.

of the whole series, this average may be far from the true average capacity of all; but we have the following reason for thinking otherwise: That capacity (1,330) which comes nearest to the above average, belongs to skull H. 7, and this it is, that next after the "type" (H. 40) is the most typical skull of the whole series as shown by its various indices.

The table of Broca, with which we have to compare this average, gives separate figures for the males and the females of each race. We have calculated the combined averages and made our comparisons with these. Broca gives 29 series including the most diverse races, but no American Indians. We find but three of his series having a lower cranial capacity than the Saladoans; these are the "Hottentots and Bushmen," the "Australians," and "Parias of Allipoor (Calcutta)." Such inferior races as the Negroes of Africa, the Papuans, the New Caledonians, and the Tasmanians seem to rank in this character above the Saladoans.

Our Table XXIV presents some small series of average cranial capacities of (lower) races represented in the Army Medical Museum. They are taken from the series of 101 (see Table LXXXI)—2 Navajos and 10 Peruvians being added. All the races, not American Indians, mentioned in this table, viz, Sandwich Islanders, Mongolians, New Zealanders, American Negroes, and Eskimos, it will be seen, have larger brain cases than our Saladoans. The position of the latter with regard to other autochthones of both North and South America is shown in the following extract from the table:

(1) Siouan tribes	1463
(2) Pah Utes	1367
(3) Apaches	1331
(4) Ancient Californians	1323
(5) Navajos	1315
(6) Saladoans	1313
(7) Peruvians	1295

It is not in accordance with current theories that a people as advanced in arts and social organization as that of the Salado Valley evidently was should have a cranial capacity superior only to such low races as the Hottentots and Australians. It must be borne in mind, too, that the uncremated remains of the Saladoans probably represent a superior class of this community. Still, small as is their cranial capacity, it is greater than that of the Peruvians, who were a race more advanced than the Saladoans. We have little to suggest in explanation of these facts. Perhaps the subject of cranial capacity in relation to culture may have to be reconsidered. The Saladoans were a people of low stature and rather slight physique, and the relation which the skull bears to the rest of the skeleton may be a factor in the problem. We have as yet no evidence to show that distortion reduces the capacity of the cranium.

§ 14. THE TYPE SKULL

The following method is the one we have adopted for selecting a type skull from the series: First. Let all the sets of indices be arranged in ordination. Second. Subtract the lowest index in one ordination from the highest. Third. Divide the difference by 2, and add the quotient thus obtained to the lowest index. This gives the theoretical mean of variation. Example: Suppose we have a series of skulls with cephalic indices ranging from 80.00 to 90.00. The first step, subtraction, gives us 10.00; the second step, division, gives us 5.00, and the third step, addition, gives us 85.00, which is the theoretical mean of variation. The skull, if any, having this index is the type of the series as far as concerns the cephalic index. In practice, however, where we calculate indices to the second decimal place, it is not usual to find any skull with the index exactly expressing the theoretical mean. The skull most nearly expressing it is taken as the type.

It follows that if we take many different series of indices upon the same skulls we have to determine what skull stands in the plurality of instances nearest the theoretical mean. Suppose we calculate ten different series of indices upon 9 skulls (an odd number is easier for the purpose of explanation). If 1 particular skull expresses the theoretical mean of variation in

each and every series, it is, of course, the type skull of the lot in every respect, so far as the investigation has gone.

But if, as must always be the case, no skull expresses the theoretical mean of every series of indices, then we take the skull which averages nearest the theoretical mean. Therefore, of our supposed lot of 9 skulls we select, let us say, from the first series of indices, 3—the skull having an index most nearly expressing the mean of variation, the skull having an index next greater than this, and the skull having an index next smaller. Now, supposing that we have ten series of indices, let us say that the skull which expresses the theoretical mean of the first series comes nowhere near it in any other series, while the skull next below the theoretical mean in the series of indices under consideration is the theoretical mean of two other series of indices, and stands either just above or just below the mean in every series. The latter, then, is very likely the type sought.

To state it more methodically: We have measured a lot of skulls, have reckoned their indices, and have arranged the several different kinds of indices in as many different ordinations. In each ordination we select the index most nearly expressing the mean of variation and call it No. 1; the index next above and index next below this we call No. 2. The index next above the greater No. 2, and the index next below the lesser No. 2 we call No. 3, and so on. Now let us add together, for each skull separately, the Nos. 1, 2, 3, etc., expressing the position of the several indices with regard to the theoretical mean of radiation of each series of indices. Divide the sum thus obtained by the number of series of indices. The skull whose indices thus treated give the lowest quotient is the type.

In the present case, however, it must be remembered that the Salado skulls are much broken, so that only a few can yield a complete series of measurements. The type skull, therefore, in part owes its selection to its good preservation, it being represented in every series of indices. It can not be said to be the type of 57 skulls, perhaps, but in a general way, all things considered, it is the best representative of the characteristic dimensional relations of crania of the people in question. Its most aberrant feature consists in the unusal height of the orbits, shown by the orbital index 96.05, while the theoretical mean of the orbital indices is 90.90.

The type skull thus selected is II. 40; its five views are shown in plates 55 to 59, inclusive. Of skulls in good condition II. 7 and II. 15 approach nearest to the type.

§ 15. PROCESSES AT BASE OF SKULL.

There is evidence, in the archæologic find of Los Muertos and Las Acequias in the shapes of the pottery, etc., that this people, like the modern Pueblos, were accustomed to carry heavy burdens on the head. Such being the case, we might reasonably expect to find the various processes for muscular and ligamentary attachments at the base of the skull strong and prominent; but, on the contrary, we find them unusually subdued and weak. It may be that our expectations are unfounded; that the load on the head, once well balanced, required little muscular exertion to sustain it.

The Inion.—In 46 adult skulls, with this process well preserved, compared with the five forms of Broca,* we find that 27 agree with his zero or lowest form, that 19 resemble his No. 1, and that none are to be considered of a higher grade than this. It has been conjectured that the general pressure which has flattened the occiput in these skulls may have hindered the full development of the inion; but the fact that all the processes of the base are weak, and that the inion is ill-developed in skulls where the pressure did not fall upon it, seems to indicate that pressure can at most account for only a part of the subdued features of the inion in this series.

§ 16. THE PTERION.

Of the pteria 32 are sufficiently preserved to be studied with profit. They occur in 24 skulls, 13 on the right side, 19 on the left. Four exhibit the character plainly, but can not be measured. The remaining 28 (see Table XXV) are easily measured. Only 8 skulls have the pteria intact on both sides.

*Broca: Instructions craniologiques et craniometriques. Pl. VI.

All are of that form called by Broca pterion in H. Wormian bones complicate their characters.

Of the 11 measurable right pteria the longest is 20^{mm} (the maximum of the group) and the shortest is 5^{mm}. Of the 17 measurable left pteria the longest is 18^{mm} and the shortest 3^{mm} (the minimum of the group). The average length of the right pteria is 12.90^{mm}; the average of the left pteria is 11.35; the average of all, 11.96.

There are but two pteria of less than 8^{mm} in length, a percentage of 6.5, which is smaller than any on Anoutchine's* table except that of the Peruvians, which is 3.4. There is but one pterion which does not exceed 3^{mm}, but with our small total of 28 this gives us a percentage of 3.5.

On the whole the character of the pterion is of a very high type.

§ 17. UNIQUE SAGITTAL SYNOSTOSIS.

The presence among the Saladoans of 4 skulls showing unique sagittal synostosis, one of them adolescent, has naturally led us to inquire if an early sagittal synostosis can be a physiological characteristic of this people, or if, at whatever age synostosis begins, it affects first the sagittal suture. With this point in mind we have investigated several other series of American skulls with the following results (the description applies solely to the outer table except in cases where the inner is expressly mentioned):

Saladoans.—The Saladoans present four cases of unique sagittal synostosis as follows:

No. H. 15, a fairly well-preserved skull, female; basilar suture closed; third molars cut except left lower (?); right lower second premolar and first molar shed and alveoli absorbed; right upper third molar decayed away; the two third molars still visible; lower right and upper left one only slightly worn, especially the latter; premolars and first molars worn just into the enamel. Sagittal suture completely obliterated; no other synostosis. A line of porosity across the pre-occipital may possibly indicate previous existence of an *os epactale*.

No. H. 17, a well-preserved skull of a youth; basilar suture open; all milk teeth shed; no third molars cut; no permanent teeth lost ante-mortem; enamel of first molars a little worn; entire obliteration of sagittal suture; no other synostosis of brain capsule.

No. H. 45, a fairly well-preserved female skull; basilar suture closed; full set of permanent teeth cut and none of them lost ante-mortem; wear of enamel very slight; complete sagittal obliteration; no other synostosis.

No. H. 49, a much warped and laterally flattened skull; post-mortem distortion; basi-occipital broken away; full set of teeth, except lower third molars, cut and none shed ante-mortem; lower third molars point forward and are impacted against second molars, probably never would have been erupted through gum; first molars worn, but not into dentine; obliteration of sagittal suture; probably no other synostosis; sutures of cranial vault all very simple.

Peruvians.—Among the Peruvians the following cases are to be noted in connection with sagittal synostosis:

No. 2315, a well-preserved skull without mandible; basilar suture closed; permanent teeth all erupted and none lost ante-mortem; all teeth lost post-mortem except left upper first premolar and molar; these teeth worn into the dentine; posterior two-thirds of sagittal suture obliterated; anterior third ossified in spots; no other synostosis; there is a slight ridge about the anterior part of the sagittal suture; the left temporal sends a process to join the frontal bone.

No. 2506, a well-preserved skull without mandible; basilar suture closed; teeth all cut, but third molars lost ante-mortem; all teeth which are present are worn down to the dentine; complete sagittal obliteration; a very little commencing synostosis of the lambdoid and left occipito-mastoid sutures; no other synostosis; sagittal ridge; a process joins right temporal and frontal.

No. 2945, a well-preserved skull with mandible; basilar suture closed; all permanent teeth cut; both upper third molars and left lower third molar shed ante-mortem; teeth worn down to the dentine; complete obliteration of sagittal and complete obliteration of right squamous suture; no other synostosis; sagittal ridge.

*ANOUTCHINE: Sur quelques anomalies du crâne humain et de leur fréquence dans les races. Review by C. de Mérejkowsky in Revue d'Anthropologie, 2d series, vol. 5 (1882), p. 359, *et. seq.*

It is seen from these notes that the Peruvians offer no case of sagittal synostosis comparable to that of the Saladoans. This is the conclusion arrived at by considering that all three of the above skulls are at least mature and show a sagittal ridge.

Yucatecs.—The Yucatecs offer the following specimens of unique sagittal synostosis:

No. 626, a well-preserved skull without mandible; basilar suture closed; all permanent teeth cut; second upper right premolar shed ante-mortem; teeth not worn; sagittal suture obliterated; no other synostosis.

No. 628, a well-preserved skull without mandible; basilar suture closed; all permanent teeth cut; left upper third molar lost, probably ante-mortem; enamel of teeth not worn; sagittal suture obliterated; a little commencing synostosis just above the lambda; no other synostosis.

Californians.—No. 1415, small, rather heavy and well-preserved; basilar suture closed; third upper molars cut (lower jaw not found); right upper third molar lost; the teeth show wear sufficient to slightly expose the dentine except in the case of the left upper third molar, of which the enamel alone is worn; the sagittal is coössified throughout its entire length on the inner table, and all but its anterior fifth on the outer table; no other synostosis.

No. 1430, medium size; facial bones separated from cranium and only right side of mandible preserved; third molars cut; but all but right lower have been lost; basilar suture closed; the enamel only of the teeth is worn; sagittal entirely obliterated; no other synostosis.

No. 1507, small skull; right temporal and cerebellar regions broken away; mandible broken across the symphysis; basilar suture closed; all third molars cut, but right upper one has been lost; the second and third molars have their enamel only worn; some other teeth have their dentine slightly worn. The sagittal is coössified entirely on the inner table and all but its most anterior portion on the outer table; no other synostosis; lambdoid quite complicated.

No. 1748, consists of the cranial vault, only, from a good-sized, rather scaphoid specimen; sagittal completely obliterated on each table; coronal and lambdoid fully open; no way of judging age.

A skull which is less satisfactory to discuss, as all its teeth have dropped out post-mortem, is No. 802, a well-preserved recent skull; basilar suture closed; third molars cut; all teeth dropped, but there is no alveolar absorption. There has been a large *os epactale*; it is now firmly coössified to the parietals, and they in turn to each other, the sutures being thoroughly obliterated; other sutures, including that between the epactal and occipital, open. Rather a scaphoid skull.

In many of the Californian skulls there is a prominence, sometimes prolonged into a ridge, just behind the bregma; none of the above synostotic skulls show this peculiarity except No. 802, which has a slight ridge. In some skulls, however, where synostosis is more general and probably a purely senile change, it is evident enough.

Mound builders.—No. 556, a mutilated skull of a Floridian without mandible; state of basilar suture indeterminable; upper set of permanent teeth all cut; right upper third molar shed ante-mortem, teeth all deeply worn; complete sagittal obliteration; no other synostosis.

No. 1110, a mutilated skull of a Floridian without mandible; basilar suture closed; teeth mostly shed ante-mortem and rear alveoli much absorbed; sagittal obliterated except at its anterior half centimeter; very slight commencing synostosis of lambdoid; no other synostosis of brain capsule. This is probably the skull of quite an old person.

No. 730, a fairly well-preserved skull from Kentucky with mandible; basilar suture open; all permanent teeth cut except third molars; no teeth shed ante-mortem; all teeth lost post-mortem except right upper first molar and both lower first molars; these teeth are not worn; sagittal suture open anteriorly for its first 18 millimeters; behind this it is obliterated to within 16 millimeters of the lambda, and the space of these last 16 millimeters is partially co ossified; no other synostosis. As far as age and a globose appearance are concerned, this skull is essentially similar to the Saladoan, H. 17.

No. 1012, a large, well preserved skull, with mandible, from Illinois; basilar suture closed; all permanent teeth cut; right upper molars, left upper first and third molars, and both lower first molars shed ante-mortem and alveoli absorbed; teeth somewhat worn; complete sagittal oblitera-

tion; synostosis of coronal right and left between stephanion and pterion; fronto-sphenoid sutures coössified right and left; very slight commencing lambdoid coössification. This skull is interesting, not because the sagittal synostosis is unique, but because it is so complete and apparently so much in advance of the other synostoses, while it retains a globose shape, being notably rounded in its outline.

No. 1662, a well-preserved skull, with mandible, from Dakota; basilar suture closed; permanent teeth all cut and none of them shed ante-mortem; teeth show some wear; sagittal suture obliterated except its anterior two centimeters; no other synostosis.

Alaskans.—Sagittal synostosis unaccompanied by other synostoses is not conspicuous. Only the following two, the first of which is very remarkable, are worthy of note:

No. 2454, perfectly preserved, from a child between 7 and 10 years old; basilar suture open; sutures between basi-occipital and exoccipitals partly open; premaxillary suture visible on palatine vault; first permanent molars cut and second appearing; upper median, lower median, and lateral incisors cut but lost; no permanent canines or premolars; posterior two-thirds of sagittal suture entirely closed on outer and inner tables; for one-half of the remaining third there is partial synostosis on both tables, while the anterior sixth is open; no other synostosis.

No. 2486, a perfectly preserved skull of an adult; basilar suture not quite closed; lower third molars not cut; posterior two-thirds of sagittal firmly coössified; half the remainder partially so; anterior extremity open; coössification also, but less complete, of right coronal between sagittal and temporal line, right lambdoid and left parieto-mastoid.

Eskimos.—Among the Greenland Eskimos there is no case of sagittal synostosis, alone, comparable with that of the Arizonians. There is found, however, the following extraordinary specimen:

No. 1226, a skull without mandible, of light weight and well preserved; basilar suture open; teeth lost post mortem, except the right upper molars, three in number, and left upper first molar; both third molars cut. The one remaining in the skull is not worn, nor is the second molar much worn; dentine of first molar worn a little; complete sagittal obliteration; also complete lambdoid obliteration except about $5^{mm.}$ of the left lateral end; no other synostosis. Thus the whole posterior end of the skull from the coronal suture above to the basilar suture below is a single bone.

We conclude then: First, that unique sagittal synostosis may take place at a very early age; second, that it does not necessarily produce a scaphoid skull; third, that it may or may not be accompanied by a sagittal ridge; fourth, that at present it can not be said to be peculiarly characteristic of any American race.

Percentages representing the number of cases of unique sagittal synostosis in relation to the total number of skulls in each given series might be reckoned; but they would probably not accurately represent the tendency to unique sagittal synostosis for the following reasons:

First. It is most likely true that under a certain age no skull is liable to sagittal synostosis except for pathological reasons. Diseased skulls should of course be excluded from consideration and not be allowed to affect the percentage. But, inasmuch as we have learned that sagittal synostosis may take place before the skull is matured in any other respect, we must confess ourselves at a loss to determine exactly what that age is. So then we must either draw an arbitrary line between two supposed classes of skulls, the one of which is liable and the other not liable to sagittal synostosis, or we must consider every skull as liable to it. In neither case can our per centage exactly represent the facts.

Second. Cases of sagittal obliteration may occur which are striking in their completeness, but which are accompanied by very slight disseminated synostosis of other sutures. In determining whether such cases are to be allowed to affect the percentage or not, personal judgment—always a little arbitrary—must be used.

Third. Cases may occur where the sagittal is coössified but not entirely obliterated, while all other sutures are completely open. This occurrence in a young skull merits mention; but here again fallible judgment is called into play to pass upon the age of the skull and the minimum amount of synostosis entitled to mention.

In an article entitled "Nachtrag zur Anatomie der Schädelnähte," by Dr. E. Zuckerkandl,* in a series of 134 skulls, mostly Negroes, Negritos, and Malays, we find the following notable cases:

No. 98: Indian (American?), sagittal suture obliterated in places. No synostosis of coronal, lambdoid, or mastoid sutures.

No. 104: Peruvian, sagittal totally obliterated; other sutures open.

No. 124: Alfuru, sagittal obliterated in places; other sutures open.

No. 128: Javanese woman, sagittal totally synostosed; other sutures open.

In none of these cases does the author note a senile appearance of a skull, as seems to have been done when required throughout the article.

Unfortunately we do not possess a copy of Dr. Davis's work† on synostosis of cranial sutures where this subject is discussed. He refers to it, however, in his "Thesaurus Craniorum," which we quote:

I have * * * * * pointed out that *scaphocephalism is far from being the usual result of the early ossification of the sagittal suture*. This position is maintained by an analysis of the twenty-seven skulls in this collection which present no appearance of sagittal suture, but only four of which are true *scaphocephali*.‡

Continuing, he refers particularly to four of these cases of synostosis, which we quote accordingly, omitting the measurements.

No. 100: African negro, male, æt. c. 30; presents a complete obliteration of the sagittal suture but no *scaphocephalism* or other deformity. The alisphenoids and parietals only just touch.

No. 378. Pokomame; imperfect calv. * * * an instance of premature ossification of the sagittal suture which is totally obliterated. The other sutures are all open. * * * In the synostosis of the parietals in the case of a calvarium artificially deformed in so extreme a degree and in a direction running parallel to the sagittal suture; it is, I believe, unique. There is not the slightest approach to scaphocephalism.

No. 915: Australian, female, æt. c. 17. This small cranium is synostotic from premature obliteration of the sagittal suture, which has not materially changed its form. It can not be denominated scaphocephalic at all. It exhibits marks of old injuries on the frontal, parietal, and occipital bones, and has no spheno-parietal sutures.

No. 789: Fatuhivan, male, æt. c. 17. This calvarium of a young subject is very large, thin, and in appearance swollen out as if it had been hydrocephalic. It is also synostotic, the sagittal suture being totally obliterated; yet the calvarium is not *scaphocephalic*, nor indeed deformed in any way.§

§ 18. THE INCA BONE AND ALLIED FORMATIONS.‖

Perhaps the most interesting feature discovered in this series is the great prevalence of the Inca bone and its kindred anomalies. This was first observed by Dr. Wortman while he was engaged in collecting and preserving the bones as they were exhumed at Camp Hemenway in the Salado Valley in 1887. He had, however, no opportunity in the field for making a careful study and determining the comparative frequency of the anomalies; besides, the bones when unearthed were in such a friable condition that they could not properly be examined until they were strengthened and repaired. Since they have been repaired at the Army Medical Museum we have found, among complete skulls and fragments, a series of 88 occipital bones in a sufficient state of preservation to be examined for these formations.

We need not enter into an elaborate description of these anomalies, nor discuss at length their morphological characters. Such elaboration is not within the general plan of our work. The accompanying illustrations will, we hope, serve to make clear to the reader, when the text may be too concise, the full meaning of the terms we employ. Those who desire to consult the original authors whom we have followed are referred to the works of Virchow,¶ Anoutchine,** and Topinard.††

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* *Zuckerkandl, E.* in Mittheilungen der Anthropologischen Gesellschaft in Wien, Band IV, 1874, p. 144 *et seq.*

† Davis: On synostotic crania among Aboriginal Races of Man. Haarlem, 1865.

‡ Davis: Thesaurus Craniorum, London, 1867, p. 57.

§ Davis, op. cit., pp. 195, 235, 261, and 321.

‖ Much of the material in this section has appeared previously in an article, by the author, entitled "The Inca bone and kindred formations among the ancient Arizonians." American Anthropologist, Washington, D. C., Vol. II, p. 337 (October, 1889).

¶ Virchow: Ueber einige Merkmale niederer Menschenrassen am Schädel. Berlin, 1875. Zeitschrift für Ethnologie, v. 20, 1888, p. 470.

** Revue d'anthropologie, 1883, p. 140 (Review).

†† *Op. cit.*, p. 769, p. 791, foot note.

In the first place we will consider the true epactal bone, or *os Incæ*. It exists in all races; it becomes a characteristic of the Peruvian or Inca race only by reason of its great frequency among them. How often it is found in them more than among other peoples hitherto studied will be seen in the accompanying table (Table A).

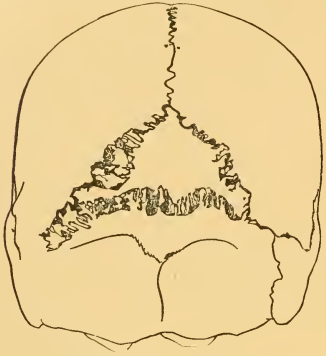

FIG. 31—Inca bone (No. H. 13).

FIG. 32—Inca bone (No. H. 29).

Figs. 31 and 32 represent typical forms of this bone in two varieties described by Virchow.* In one the persistent transverse occipital suture runs directly from one asterion to the other, and seems but a continuation of the parieto-mastoid suture. In the other the ends of the transverse

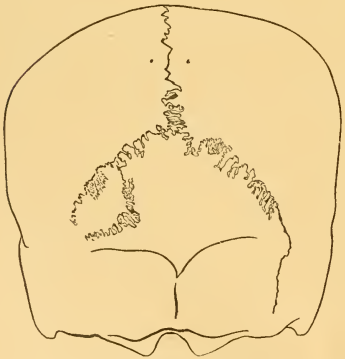

FIG. 33—Incomplete Inca bone (No. H. 14).

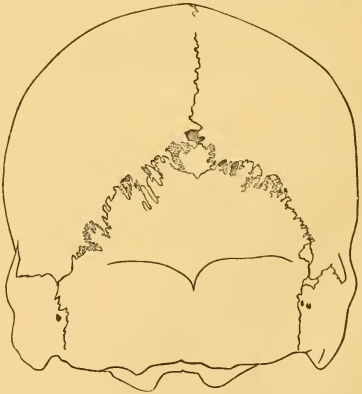

FIG. 34.—Quadrate bone (No. H. 48).

suture join the lambdoidal on each side, a short distance above the asterion. The epactal bone shown in Fig. 31 was complicated with a multitude of Wormian bones, many of which, very minute, pertained to the outer table only, and, falling out, left the broad, indefinite border shown

* Zeitschrift für Ethnologie, 1888, p. 470.

in the figure. In our series of 88 we have 5 *ossa Incæ* as true and typical as these—a percentage of 5.68.

Fig. 33 represents the only specimen in the Salado series of what Anoutchine calls the incomplete *os Incæ*. In this the left third of the transverse suture is persistent and, connecting with the lambdoidal suture above by an almost vertical suture, separates from the rest of the occipital a triangular bone which probably represents one original point of ossification. This added to the complete *ossa Incæ* gives us 6 specimens or a percentage of 6.81 of both these forms combined.

As an anomaly which is sometimes confounded with the epactal bone, though having a very different embryologic origin, the quadrate bone, or *os quadratum*, is to be considered. Fig. 34 illustrates the only specimen in the collection which can with any propriety be classed under this head, and it is neither a large nor a typical specimen. Some might be inclined to regard it as a triquetral bone. One instance of this form in 88 occiputs gives us a percentage of 1.13.

Immediately above the apex of the quadrate bone in Fig. 34 is seen an open space, which was evidently once filled by a small *os sagittale*.

Fig. 35.—Apical bone associated with Wormian bones (No. H. 51).

Fig. 36.—Possible vestige of transverse suture (No. H. 15).

Every separate ossicle or collection of ossicles observed at the apex of the occipital, except a quadrate or an epactal bone, is placed in Virchow's class of *ossa triquetra seu apicis* (apical bones, we shall call them), even when it lies entirely on one side of the median line or is one of the numerous series of Wormian bones like that shown in Fig. 35. It has been found difficult or impossible to draw a definite line of distinction between such and the most typical *os apicis*.

In including all these forms in this class we may have exceeded the limits set for themselves by other observers, and this may account for the large number (16) and the comparatively high percentage (18.1) of *ossa apicis* which this collection furnishes. But if none but the most certain examples were tabulated we would still, probably, have a higher percentage than is to be found in any other race.

There is one anomaly which we have not tabulated, namely, the vestige of the tranverse suture which is sometimes seen in the neighborhood of the asterion on one or both sides and which often extends but a few millimeters in the direction of the median line. This is omitted because of the uncertainty attending the examination of minute examples arising from abrasions to the outer table, post-mortem marginal fissures, and other injuries common in these old and friable bones.

In this connection I introduce Fig. 36. Here we see a peculiar punctured or honeycombed appearance of the outer table in the line of the transverse suture. It seems to be a vestige of that suture of unusual character confined to the outer table. It is the only specimen of its kind in the Hemenway collection, but there are some similar formations in the general collection of our museum.

The following table is made up of four of Anoutchine's tables, consolidated, with the following modifications: (1) All the races are placed in one order and are called by one name. (2) A title in his table of "Americans in general" is omitted; it would serve in connection with this paper to confuse rather than to enlighten the reader; its figures are obtained merely by adding those of the "Peruvians" to those of "Americans not Peruvians." (3) The Saladoans have been added and placed at the head of the list. Anoutchine's percentages are based on a liberal number of specimens, ranging from 157 in Australians and Tasmanians to 6,871 in Caucasians, in general. The Peruvian specimens are 664; and the Americans (not Peruvians) are 390 in number.

TABLE A.—*Showing the percentage of the Inca bone and allied formations as found in various races.*

Races.	Complete *os Incæ*.	Complete and incomplete *os Incæ*.	*Os quadratum*.	*Os triquetrum seu apicis*.
Saladoans	5.68	6.81	1.13	18.1
Peruvians	5.46	6.68	1.05	10.5
Americans, not Peruvians	1.30	3.86	0.26	5.63
Negroes	1.53	2.65	2.11	1.19
Malays and Polynesians	1.09	1.42	0.76	0.43
Mongolians	0.56	2.26	0.57	3.02
Papuans	0.57			
Caucasians in general	0.46	1.19	0.18?	1.59
Caucasians of Asia	0.51	1.70	0.41	2.36
Europeans	0.45	1.09	0.13?	1.42
Melanesians		1.65	0.62	2.87
Australians and Tasmanians	0.0?	0.64?	0.64	0.64?

The above table speaks for itself and but little comment is necessary. It shows a most remarkable correspondence in the frequency of these anomalies between the Saladoan and Peruvian races. It shows also that, while in respect to three of the anomalies the Peruvians are widely separated from the rest of the human race, as heretofore studied, the Saladoans are still farther removed. In short, they out-Inca the Incas.

It has been maintained* that the artificial pressure to which Peruvian skulls were subjected produced the anomaly of the epactal bone. We consider that the arguments in favor of this theory are already successfully refuted, but will nevertheless add to the refutation such testimony as the Hemenway collection offers. The Saladoan skulls bear not the slightest evidence of intentional depression or distortion of any kind, especially of that sort produced by the application to the forehead of the head board, such as the Peruvians once used and some Indians of the northwest coast still use. A certain amount of accidental or unintentional occipital depression is to be found in the majority of the skulls, due apparently to the use of a wooden-backed baby basket with an insufficient pillow; but it is a depression of no greater degree or frequency than is found in many American races among which the epactal bone is comparatively rare. Furthermore, it is not in the most depressed occiputs of the Saladoan skulls that the epactal bone is most common, but in those that are fairly rounded and prominent.

§ 19. FACIAL INDICES.

Being somewhat uncertain as to the true position of the ophryon in these skulls, we took neither the ophryo-mental nor the ophryo-alveolar measurements of Broca, and hence we were unable to compute the facial indices of that author. We have contented ourselves with securing the facial heights of the Frankfurt agreement, which have the definite point of the nasion for their upper landmark, and from these we have computed four indices prescribed by the agreement, namely: The total facial index of Virchow, the total facial index of Kollmann, the upper facial index of Virchow, and the upper facial index of Kollmann. (Tables XXVI to XXXIII, inclusive.)

As much as we have gained in precision by this selection we have lost in another way, since

* Dissertation sur les races qui composaient l'ancienne population du Pérou. Par M. L.-A. Gosse, Docteur en Médecine. Mémoires de la Société d'anthropologie, vol. I.

the data for comparison of the French measurements are rich, while those for the measurements of the German school are meager. Scattered through the pages of the *Zeitschrift für Ethnologie* and the accompanying *Verhandlung der Berliner Gesellschaft für Anthropologie, Ethnologie und Urgeschichte* there are many separate papers by Prof. Virchow (see Table LXXIX). From these we have prepared, with the expenditure of considerable time and care, Table No. LXXX, and from this we quote a few items for comparison in the facial indices.

We have compiled the following eight tables of comparison, which appear in this section, largely from our own very insufficient special series of 101 before referred to (Table LXXXI). Tables B, D, F, H, show the relations of this Saladoan collection to various races of the world, and Tables C, E, G, I, show its relations to other Indian tribes. Where anything is added from Table No. LXXX the source is indicated in a footnote.

The facial index of Virchow, which is the product of the naso-mental height multiplied by 100 and divided by the facial width of Virchow—a line uniting the inferior extremities of the malo-maxillary sutures—has been computed in 19 skulls. These indices are shown in Tables XXVI, XXVII, where it appears that they vary from 102.85 to 131.25, and that their average is 117.64. For this index, according to the "agreement," the dividing point between the two classes of broad faces and narrow faces is an index of 90, all above this being narrow and all below, broad. These skulls are therefore decidedly narrow faced, but so it would appear are all races as represented in our series of 101, as shown in the following tables:

TABLE B.—*Facial index of Virchow among various races.*

Races.	Number of skulls.	Average index.
Europeans	5	131.77
Negroes	3	127.83
Chinese	2	118.78
Fiji Islanders	2	118.61
Eskimos	6	118.35
Saladoans	19	117.64
Australians	2	117.02
Japanese	2	116.61
Sandwich Islanders	2	115.71
North American Indians excluding Saladoans	30	114.83
Malays (Virchow)	3	*111.50

*From Table LXXX.

TABLE C.—*Facial index of Virchow among American tribes.*

Races.	Number of skulls.	Average index.
Pawnees	1	123.15
Pah Utes	5	117.72
Saladoans	19	117.64
Sioux	4	116.01
Californians	8	115.91
Apaches	4	114.72
Chippewas	2	113.63
Navajos	3	110.29
Poncas	3	108.31

We have been able to compute the upper facial index of Virchow in 34 skulls. This index is the product of the naso-alveolar height multiplied by 100 and divided by the facial width of Virchow. In the tables of this measurement (Tables XXVIII, XXIX) we find that the minimum is 62.22, the maximum 79.59, and the average 69.82. For this index 50 constitutes the point of division between broad and narrow upper faces. The skulls in this group, then, are all distinctly of the latter class. In the tables below it will be seen that there are no averages below 50. In other words, there are no broad upper faces in our special series of 101.

TABLE D.—*Upper facial index of Virchow among various races.*

Races.	Number of skulls.	Average index.
Europeans	14	75.82
Negroes	6	74.35
Chuckchees	2	73.48
Eskimos	11	72.90
Fiji Islanders	2	72.48
Chinese	2	72.02
Australians	3	71.49
North American Indians, excepting Saladoans	44	70.70
Botocudos	11	*70.00
Saladoans	34	69.82
Japanese	2	68.94
Sandwich Islanders	6	68.19
Various Malaysians	24	67.90
New Zealanders	4	66.85
Motilo	1	*66.00
Yucatecs	1	*65.70

* See Table LXXX.

TABLE E.—*Upper facial index of Virchow among American tribes.*

Races.	Number of skulls.	Average index.
Seminoles	2	81.17
Minnetarees	2	79.36
Pah Utes	7	72.49
Sioux	4	71.99
Californians	10	70.96
Pawnees	2	70.66
Saladoans	34	69.82
Apaches	6	69.01
Ponkas	4	68.51
Navajoes	4	66.88
Chippewas	2	65.94
Cheyenne	1	65.13

In 17 skulls we have been able to ascertain the total facial index of Kollmann, which is found by multiplying the naso-mental height by 100 and dividing the product by the bi-jugal width. The tables of this index (XXX, XXXI,) present a minimum of 81.53, a maximum of 97.65, and an average of 88.01. The classes of this index, like that of the facial index of Virchow, have their dividing point at 90; all skulls with an index below that being chamæprosopic or low-faced, and all above that being leptoprosopic or high-faced, the equivalent of Virchow's narrow-faced skulls. Our Saladoan skulls, therefore, which, according to the classification of the Virchow index, are all narrow, are, according to the classification of the Kollmann index, mostly broad (low) and have a slightly broad average.

In the following table (F) of ten different races, in which only two races—Europeans and Negroes—have high faces, the Saladoans appear in a median position and nearer the true Mongolians than to other Indian tribes:

TABLE F.—*Facial index of Kollmann among various races.*

Races.	No. of skulls.	Average index.
Negroes of Africa	6	*95.40
Europeans	5	92.80
Negroes of America	3	91.95
Fiji Islander	1	89.58
Botocudos of Brazil	3	*89.10
Japanese	2	88.95
Chinese	2	88.63
Saladoans	17	88.01
Eskimos	6	87.71
Sandwich Islanders	2	84.86
Australians	2	84.59
Various Malaysians	8	*84.30
North American Indians (excluding Saladoans)	29	83.74
Goaziros of Venezuela	8	*83.30

* See Table LXXX.

In the following table (G) of nine North American tribes it would appear that the Saladoans have higher faces than any other tribe:

TABLE G.—*Upper facial index of Kollmann among various tribes.*

Races.	Number of skulls.	Average index.
Saladoans	17	88.01
The Rock Bluff skull	1	*86.50
Californians	8	85.66
Apaches	4	84.87
Pawnees	1	84.78
Pah Utes	5	83.18
Navajoes	3	83.22
Sioux	4	82.39
Ponkas	3	80.74
Chippewas	1	80.00
The Calaveras skull	1	*76.30

*From Table LXXX.

In 27 skulls the upper facial index of Kollmann has been computed (Tables XXXII, XXXIII) its minimum is 47.05, its maximum 60.93, and its average 52.48. In this index, as in the analogous index of Virchow, the highest figure for low or broad upper faces is 50. Of the Saladoans 6 out of 27 belong to this class; the rest have high upper faces, and the average is leptoprosopic. As shown in Table I, the Saladoans for this index have higher upper faces than other Americans in general; but three American tribes exceed them in this particular.

TABLE H.—*Upper facial index of Kollmann among various races.*

Races.	Number of skulls.	Average index.
Chuckchees	2	55.17
Eskimos	10	54.09
Veddahs	.....	*53.80
Chinese	2	53.74
Negroes	6	53.22
Europeans	14	53.06
Fiji Islanders	1	52.77
Botocudos	.....	*52.60
Japanese	2	52.58
Saladoans	27	52.48
North American Indians, excluding Saladoans	42	51.69
Sandwich Islanders	6	50.35
Australians	3	50.23
Various Malaysians	.....	48.60
New Zealanders	4	48.54

*From Table LXXX.

TABLE I.—*Upper facial index of Kollmann among American tribes.*

Races.	Number of skulls.	Average index.
Seminole	1	58.33
Minnetarees	2	58.05
Californians	10	52.62
Saladoans	27	52.48
Pah Utes	7	52.03
Pawnees	2	51.20
Sioux	4	51.18
Navajoes	4	50.90
Ponkas	4	50.61
Apaches	6	49.55
Cheyennes	1	47.65
Chippewas	1	47.40
The Rock Bluff skull	1	*47.00
The Calaveras skull	1	*42.60

*From Table LXXX.

The upper facial index of Virchow is sometimes called "*Oberkieferindex*," an excellent name, for it is indeed an index of height and width of the superior maxillary bone. Now if this shows

narrow indices, and Kollmann's method shows broad indices, it is evident that the cause is considerable lateral development of the malar bones.

§ 20. GERMAN PROFILE ANGLE.

In 44 skulls we have determined the German profile angle or *Profilwinkel* of the Frankfurt agreement. We place these angles on record (tables XXXIV, XXXV) more for the advantage of future students than for any benefit they may be to us in the comparative study of this collection, since among the craniometrical literature to which we have access we find few data on this point. The following table we have compiled from works of Wieger* and Tarenetzky,† including in its proper order the average of the Salado series:

TABLE J.—*German profile angle in various races.*

Race.	Number of skulls.	Average index.
Russians (Tarenetzky)	184	87.70
Americans (Wieger)	15	85.21
Peruvians (included in Americans)	3	84.33
Europeans (Wieger)	15	84.13
Saladoans	44	83.25
Egyptians (Wieger)	19	82.31
Negroes (Wieger)	16	80.52

These figures are somewhat contradictory to those of the gnathic index of Flower, which is designed to express the same character, still the relation of the Saladoans to the Europeans is much the same according to both systems of measurement.

The following is a table of profile angles taken from skulls of various races and tribes in the Army Medical Museum and arranged in order from the highest to the lowest.

TABLE K.—*German profile angle among various races, Army Medical Museum.*

Races.	Number of skulls.	Average index.
Europeans	12	86.25
Mongolians	6	84.75
Sandwich Islanders	6	83.66
North American Indians (exclusive of Saladoans)	43	83.54
Saladoans	44	83.25
Eskimos	10	82.60
Fiji Islanders	2	82.00
New Zealanders	3	81.56
Negroes	5	80.10
Australians	2	78.75

The "North American Indians" grouped under one head in the above table are divided into their separate tribes in the following table, the Saladoans being included in their proper order.

TABLE L.—*German profile angle among American tribes.*

Tribes.	Number of skulls.	Average index.
Minnetarees	2	86.00
Ponkas	4	86.00
Pawnees	2	85.75
Seminoles	2	85.50
Cheyennes	1	85.50
Navajoes	4	85.25
Sioux	4	85.25
Chippewas	2	84.25
Apaches	6	83.58
Pah Utes	6	83.25
Saladoans	44	83.25
Californians	10	79.55

* Die anthropologische Sammlung des anatomischen Instituts der Universität Breslau, bearbeitet von Dr. G. WIEGER, in Archiv für Anthropologie, Vol. XV, Supplement, 1885.

† Review of article by A. TARENETZKY, in Archiv für Anthropologie, Vol. XVI, 1886.

NOTE ON THE MANNER OF TAKING THE GERMAN PROFILE ANGLE.

This measurement is taken by Spengel's craniometer, an instrument of great accuracy but of rather limited usefulness. A close description of its mechanism is too long to be given here; for such we refer to *Harless's Lehrbuch der Plastischen Anatomie*, zweite Auflage, Stuttgart, 1876, pp. 506 *et seq.*

It is sufficient for our purpose to say that, as regards the facial angle, the craniometer consists of a strong metal table whereon the skull is placed vertex downwards with its right side facing toward the operator and adjusted in the plane of the Frankfurt agreement; and of a goniometer in a plane vertical to that of the table.

It is not often that the skull is sufficiently symmetrical to allow the four points, two supra-auricular and two suborbital, of the required plane to be placed in the same level. It is practically impossible in cases where this may be done to then find the *points de repere* of the sagittal plane vertically one above another. As the goniometer is vertical to the table which serves as a fixed point from which to determine the desired plane, it is evident that in order to use it, the points in the sagittal plane must be vertically disposed. Therefore we place the skull so that the alveolar point is exactly above the nasion while both are on the midline of the machine and face the goniometer. Care is taken to see that some points in the posterior part of the sagittal plane are also in the midline. The skull is then so adjusted that the supra-auricular and suborbital points of the right side, which, as stated, faces the operator, are in the same horizontal plane. The goniometer is put in position and the angle is read.

To sum up: The angle given in this report is, except in cases of skulls with the right side broken away, taken with the skull in such a position that the sagittal plane is vertical and the right side of the Frankfurt plane is horizontal.

§ 21. GNATHIC INDEX.

In 39 cases we have been able to calculate the gnathic index of Busk and Flower, which is found by multiplying the length of the basilo-alveolar radius by 100 and dividing the product by the length of the basilo-nasal radius. The results are shown in Tables XXXVI, XXXVII, and XXXVIII, in which we find (according to Flower's classification) but two skulls that are prognathous (above 103). There are 10 mesognathous (98 to 103) and the remaining 27 are orthognathous (98 and below). The minimum of the series is 88.78 and the maximum 110.11. The average, 95.92, is orthognathous to a high degree and allows us, in respect to the character expressed by the gnathic index, to class this people along with the highest European races.*

Gosse states that one of the effects of the occipital deformation, such as these skulls exhibit (*tête deprimée par derrière*), is to diminish the projection of the lower part of the face.† Possibly we may thus explain the marked orthognathism of the Saladoans. Nevertheless we fail to discover any direct relation between the facial angle and the occipital contour in this group. Exceedingly flattened occiputs may be found as often among skulls having high as among those having low indices, and the average index of the apparently normal skulls (94.10) is less than that of the obviously flattened, when, as an inference from Gosse's proposition, we might expect it to be higher.

§ 22. ALVEOLO-SUBNASAL PROGNATHISM.

The important character of alveolo-subnasal prognathism we have examined in 27 skulls, according to the rules established by Topinard,‡ and we have tabulated the angle and the index of this prognathism with the vertical and horizontal measurements which constitute the factors of the latter. (Tables XXXIX–XLII.)

Skull H. 43 has the lowest index, 14.28, and the greatest angle, 82°. Skull H. 57 (Plate L) has the highest index, 61.53, and the smallest angle, 59½°.

The average index of the series is 37.27° and the average angle 70.03°. In the tables given by Topinard§ Americans are not included. His average index of the Malays, 37.42, is nearest to that of the Saladoans, and the factors of the index are much the same, the horizontal being 6.5 in both races. The Malay angle, 69.7°, though not the nearest to that of our collection, is but little removed from it. The angle of the Polynesians, 70.8°, and the angle of the Indo-Chinese, 70.1°, are nearest to that of our collection. Angles of other Mongoloid races, 72.6 to 71.0, are slightly higher, and consequently may be supposed to indicate some evolutionary advancement. His highest average Caucasian angle of 81.8 is not as high as the highest Saladoan, and his lowest average Namaquois of 58.2 is lower than the Saladoan lowest.

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* TOPINARD; *op. cit.*, p. 94.

† Essai sur les déformations artificielles du crâne, Paris, 1855, p. 68.

‡ "Du prognathism alveolo-sous-nasal." Revue d'anthropologie. Paris, Vol. 1, 1872, p. 642 *et seq.*

§ *Op. cit.*, p. 668, and Éléments d'anthropologie, p. 898.

§ 23. THE ORBITAL APERTURE.

Orbital apertures to the number of 38 have been measured according to Broca's instructions, and the indices computed. (See Tables XLIII, XLIV.) Of this number but 2 come within the limit of Broca's class of microseme, or orbit with a low index (below 83.0). These are in skull H. 1 with an index of 82.92, and in skull H. 22 with an index of 81.81. There are 11 in the class of mesoseme, or orbits with medium indices (88.9 to 83.0) ranging from 86.61 in skull H. 6 to 88.75, in skull H. 13. The remaining 25 are megaseme, having high indices (89.0 and above). One orbit skull H. 36, is as high as it is broad, having an index of 100, which is the maximum of this group.

In his monograph on the orbital index Broca gives average indices for 66 tribes and divisions of the human family.* Twenty-six of these are megaseme, and to this class all the American races which he mentions, 15 in number, belong. Here, too, belongs our group with its average index of 91.10.

The people having an average index nearest to that of our group are the Indians of our Northwest coast (91.12), while the flatheaded Peruvians (91.50), ancient Yucatecs (91.41), modern Mexicans (90.82), Patagonians (90.81), and North American Indians in general (90.75) are not far removed.

There are some items in the table of Broca which seem to show that antero-posterior deformation of the skulls tends to decrease the orbital index. Thus in nondeformed Peruvian skulls the index is 92.20, while in the deformed it is 91.50, and in ancient Mexican skulls the nondeformed have an index of 93.12, the deformed an index of 90.02. These are instances of deformity from intentional frontal pressure (*déformation relevée*). From the testimony of our collection it does not appear that the accidental occipital pressure has any effect. Of the 38 skulls whose orbital measurements are recorded in the tables (XLIII, XLIV) 11 belong to the apparently normal group. The average index of the latter is 91.06, which agrees closely with that of the rest of the group.

§ 24. NASAL CHARACTERS.

Nasal index.—Forty-four skulls were in a sufficient state of preservation to allow the measurements of the nasal orifice to be taken. As will be seen by the accompanying tables (XLV, XLVI) the average is 51.66, which would place them in the mesorrhinian division of Broca, *i. e.*, where representatives of the Mongoloid races usually stand. The variation in this index is wide, however, extending from leptorrhinian to extreme platyrrhinian.

Inferior border of nasal aperture.—The inferior border of the nasal aperture, *échancrure*, is of a pretty high type, to judge from the meager statistics of other races to which we have access. Topinard in his *Éléments d'anthropologie*†, gives six standards of comparison or classes for this feature as follows: A, the sharp border; A′, the slightly rounded border; B, the thick rounded border; C, the border divided into two lips or sometimes three or level (*plate-forme*); D, the depressed border, first stage of the simian groove; E, the simian groove. These six variants are named in the order of their supposed morphological advancement, A being the highest and E the lowest. Elsewhere‡ in a monograph older than his last text-book he recognizes but five types, as he had not then apparently made a distinction between A and A′. Hence, in the comparisons which follow these forms are given both separately and combined. In our collection we find so many grades of difference between these standards that it is often difficult to assign a specimen to one or the other; our decisions are often arbitrary, still we do not think we could improve the classification if we would and in all doubtful cases we have decided with special care.

In the Salado series among 48 nares in which the inferior borders can be studied we find them divided as follows: Class A, 15; Class A′, 13; Class B, 8; Class C, 6; Class D, 5; Class E, 1. The statistics given by Topinard are in numbers only. We have computed them in percentages (as we have also computed those of the Salado series), in order that we might more easily make com-

* Recherche sur l'indice orbitaire, Revue d'anthropologie, Vol. IV, 1875, pp. 616, 617.

† P. 800 *et seq.*

‡ *Du prognathisme alvéolo-sous-nasal*, in Revue d'anthr., 1872, pp. 634–639. *Du bord inférieur des narines sur le crâne et des caractères de supériorité et d'infériorité qu'il fournit*, in Bull. Soc. anthr., 1881, pp. 184–192.

parisons, notwithstanding that Topinard's series are very small, he reports on only twelve Mongolian skulls and his highest series, New Caledonians, numbers only 74.

The following table (M) is based on one in Topinard's *Éléments d'anthropologie générale*, p. 802.

TABLE M.—*Inferior border of nasal aperture in three races.*

Class.	Auvergnians.	Saladoans.	New Caledonians
A	52.05	31.25	
A'	20.54	27.08	2.70
A+A'	72.59	58.33	2.70
B	9.58	16.67	2.70
C	13.69	12.50	10.54
D	4.10	10.42	33.78
E	0.00	2.08	20.27

The following (Table N) are percentages placed in the order of numerical importance of classes A+A' as they occur in various races. They are computed from figures given by Topinard*, Saladoans added.

TABLE N.—*Inferior border of nasal aperture, Classes A+A'.*

Race.	Percentage.	Race.	Percentage.
Lower Bretons	83.87	Malays	11.90
Auvergnians	72.59	Nubians	4.55
Saladoans	58.33	Other Africans	0.00
Mongolians	33.33		

From the foregoing it would appear that the Saladoans come next to the Europeans, in the prevalence of a high form of the feature under discussion, and that they are farther above the Mongolians than they are below the Auvergnians.

Position of septum.—In 28 skulls in which the *septum narium* is preserved we find that it is straight in 4,† deflected to the left in 11,‡ and deflected to the right in 13.§

Anterior nasal spine.—We find cause for dissatisfaction in applying Broca's instructions‖ to the description of this feature in the present series. We often encounter a long, sharp ridge extending from the extremity of the spine downwards to the alveolar point; this ridge renders spines which are very prominent when viewed from above or below quite subdued when viewed laterally, according to Broca's instructions. Thus, if it were not for the existence of such a ridge, the spine of skull H. 8 would belong to class 5 of Broca, whereas with this ridge it must be placed in class 1 (see Plate 8); but, as we have no other system of description than that of Broca, we have employed it here.

Of 43 well-preserved anterior nasal spines we have 9 of class No. 1 or the least salient, 20 of class No. 2, 12 of class No. 3, 1 of class No. 4, and but 1 of class No. 5 or the most salient. See Table XLVII.

Nasal synostosis.—In seventeen of these skulls out of forty-two examined there is synostosis of at least the upper part of the internasal suture. The percentage then of nasal synostosis in some degree is 40.5. We refer to the upper end of the suture more particularly, because the lower parts of the bones are often broken away. A partial synostosis of the suture at its lower end should not be reckoned in with the others, as it may be the result of some traumatism. Skull H. 30 is probably a case of this kind, as its nasal index is very low and its nasal bones deflected. It is not counted in reckoning the percentage.

* *Op. cit.* pp. 801, 802.

† Nos. H. 1, H. 4, H. 22, and H. 29.

‡ Nos. H. 7, H. 18, H 19, H. 21, H. 25, H. 27, H. 30, H. 32, H. 34, H. 41, and H. 45.

§ Nos. H. 3, H. 6, H, 8, H. 10, H. 11, H. 16, H. 17, H. 20, H. 35, H. 40, H. 43, H. 44, and H. 56.

‖ BROCA: Instructions craniologiques et craniométriques; Paris, 1875; Planche VI.

As it is not reasonable in the present state of our knowledge to regard nasal synostosis as possible in children, we disregard four of their skulls, not letting them affect the figures either way.

It is to be noted that there is a partial synostosis in H. 17, a young skull with the basilar suture open and third molars uncut. This is the skull which is so very notable for showing utter disappearance of the sagittal suture.

§ 25.—THE PALATE.

While we have taken four measurements of the palate and one palato-alveolar measurement we have computed only one index, that of Virchow, which depends on the palatal length, from the inner alveolar border between the incisors to the point of the posterior nasal spine, and on the palatal width, taken at the level of the second molars. This we find to be essentially a maximum width, and we prefer in this case the directions of the Frankfurt agreement to those of Topinard as being the more exact. The index is computed by multiplying the width by 100 and dividing the product by the length.

In 32 skulls whose palatine indices we have been able to compute (Tables XLVIII, XLIX) the minimum index is 62.74—which indicates a very long palate—the maximum 84.61, and the average 72.94. Only 3 indices exceed 80, and, therefore, 29 out of 32 are leptostaphylin or long-palate. As none reach the figure 85 the remaining 3 are mesostaphylin or median-palate, while none are brachystaphylin or short-palate.

This series may be said to throw no light on the question of the relationship between the palatine and cephalic indices. It has been shown that in some races a long palate goes with a long skull. In the Saladoans we have a long palate associated with a short skull; but if we admit that the skulls are shortened by artificial means applied to the brain-case, only, we must consider even this negative evidence worthless.

With regard to a correspondence between the face and the palate our series offers better testimony. All the faces, as expressed by their indices, are long; so also are all the palates.

Not only is there this general agreement, but there is to a certain extent an individual agreement in this respect. In order to elucidate this point we have prepared a table (O) given below, in which we have selected for comparison with the palatine index the upper facial index of Virchow for the reason that its table gives a larger number of examples than that of any other facial index.

In columns 1 and 4 of Table O, the number of the skulls are arranged according to the ordination of the facial index but inversely, *i. e.*, the skull having the longest face comes first, and that having the shortest comes last. In columns 3 and 6 we give the order in which each skull would come if arranged according to the length of the palate, for instance: Skull H. 27 has the second longest face and the longest palate, while skull H. 19 has the seventh longest face and the shortest palate.

TABLE O.—*Relation of palatine index to upper facial index of Virchow.*

Place (inverted) in facial index series.	No. of skull.	Place in palatine index series.	Place (inverted) in facial index series.	No. of skull.	Place in palatine index series.
1	H. 14	9	12	H. 2	10
2	H. 27	1	13	H. 28	18
3	H. 43	7	14	H. 4	20
4	H. 20	2	15	H. 5	4
5	H. 10	5	16	H. 17	12
6	H. 8	13	17	H. 7	11
7	H. 19	22	18	H. 33	14
8	H. 1	3	19	H. 16	21
9	H. 11	6	20	H. 41	19
10	H. 40	15	21	H. 50	16
11	H. 45	8	22	H. 29	17

In a glance at the above table it will be seen that the longer palates, whose relative position is expressed by one figure, belong mostly to the first half of the series of 22, while those having the shorter palates belong to the second half of the series. The sums of columns 3 and 6 show

this in another way. The sum of the numbers of ordination of the higher faced half of the series is little more than half the sum of the analogous numbers of the lower-faced half, the proportion being 56.17 : 100. The most aberrant palate in the first half is that of skull H. 19; the most aberrant in the second half is that of skull H. 5.

A list of palatine depths is given in Table L.

§ 26. THE TEETH.

Dr. G. V. Black in the introduction to his article on "Dental Caries"* observes that "caries of the teeth has been known in all historic ages of the world, and wherever prehistoric human remains have been discovered traces of this disease have been found. It seems to be and to have been universal in the sense of affecting all nations and tribes of the human race. * * * It has been thought that the savage races were not so much afflicted as the civilized, but my own study of the remains of ancient peoples will not bear out this opinion. This research has, however, been limited within comparatively narrow bounds—too narrow, perhaps, to serve as the basis of conclusions. Unfortunately the literature of the subject furnishes no data that are of much value in this direction, but what there are strongly support the statements made above. * * * The studies I have been able to make in this direction indicate that the races of men that have eaten largely of acid fruits have had less decay of the teeth than those who have been debarred by their position or climate from the use of such articles of food. Generally those tribes that have subsisted largely upon flesh and grain have suffered more from caries than those that have had a more exclusively vegetable or fruit diet. Our knowledge upon this point is, however, too meager to warrant any lengthy discussion of it."

In the following study of the teeth of the ancient inhabitants of the Salado Valley we have taken occasion to make accurate notes not only of caries but also of all deformities of the dental arch, as well as the tuberculation of the superior molars. The materials afforded are fairly abundant and quite sufficient to institute an extended comparison in these respects with other races, with whose remains the Army Medical Museum is so well provided. Unfortunately the materials illustrative of those races whose diet consists exclusively of vegetables and fruits are not abundant in our collections, and it has been deemed best to limit the comparisons to peoples subsisting almost wholly upon flesh or upon a more mixed class of food. The series selected for this purpose are as follows: A series of the Alaskan Indians, whose dietetic habits are well known and who afford an excellent example of an almost exclusively carnivorous race; an unusually large series of ancient dwellers of the Pacific coast region in the vicinity of Santa Barbara, whose food was, in all probability, of a somewhat mixed character; a good series of skulls of Sioux, who furnish a typical example of the carnivorous tribes of the plains; a series of the so-called mound-builders of the Mississippi valley; and a series of the ancient Peruvians, who lived largely on vegetable food.

It is proper to state in this connection that only individuals at or below middle life have been selected, since in those races where the wear is rapid, owing, perhaps, to grit contained in the food, the pulp cavity is soon exposed, or the nutrition of the tooth is affected and disease is set up which can not be attributed, properly speaking, to premature decay or caries. We have taken as a mark of middle life the bony union or synostosis of the cranial sutures, either the sagittal or coronal, and there can be little doubt that it is usually expressive of an age of forty or fifty years Accurate comparisons beyond this limit are difficult, if not impossible, and are therefore not attempted.

The Saladoans, so far as we are able to judge, were a sedentary people, who dwelt in cities and subsisted almost wholly upon the products of the soil, which they extensively cultivated. Indian corn, squash, and other vegetable products must have formed the chief article of their diet, although the presence of charred animal remains in the ruins of their cities indicate that flesh was occasionally consumed. That their remains are pre-Columbian, and that their occupancy of the Salado Valley extended over many generations appear to be well-established facts. As explained in our introduction, it has been pretty clearly shown that some of the modern Pueblos are very

* American system of Dentistry, Philadelphia, 1886, vol. 1, p. 730.

closely allied to them in both their habits and customs. Unfortunately paucity of material for the latter precludes comparison of their dental organs, which there can be little doubt would furnish additional evidence of value.

Caries.—The subject of dental caries among the ancient inhabitants of the Salado Valley forms an interesting study, inasmuch as it furnishes us with an excellent example of the effect of a given kind of food operating for a long period in the production of tooth decay. It should not be forgotten, however, that other influences may have been in a measure responsible for much of this disease. Their skeletons generally show a remarkable prevalence of osseous disease, and if we are to judge of them by their nearest living allies the lowered vitality of the whole race had at this early date already begun to manifest itself.

Out of some 80 or more skulls we have been able to select 35 in which the sutures indicate them to have been at or under the middle period of life. Of this number 18, or about 51 per cent, exhibit caries, which in some instances has resulted in almost complete destruction of the teeth. Among this number there are also 7, or 16 per cent, in which there has been loss of teeth and absorption of the alveoli without any evidence of caries being present. Seeing the remarkable prevalence of this disease it is but fair to presume that the loss of teeth in these 7 cases is also due to decay which would bring the total up to something like 70 per cent. Out of the remaining 10, which show no evidence of caries, 2 were of very young persons, between 9 and 12 years, in whom we could not reasonably expect to find the disease developed. If therefore these should be excluded the percentage would still be further increased. Among those skulls beyond the middle period of life, fully 90 per cent show caries and loss of teeth; but of these we have not attempted accurate comparisons.

Of the ancient Peruvians we have been able to examine a much larger series—66 in all—wherein there was no bony union of either coronal, sagittal, or lambdoid sutures. In many of them, as in all the other series, teeth had been lost after death so that doubtless in some instances—where the skull has been considered in the category of "no caries"—if all the teeth were present, caries would sometimes be found and the percentage would be thus affected. These cases, however, would probably be few and little change would be necessary.

In this series there are some 8 or 10 examples in which teeth have been lost without any evidence of caries existing. It is fair to presume that some of these at least if not all are the results of dental decay. Out of the 66 there are 29, or about 44 per cent, which show caries, and if 8, in which there is loss, be added, we have the percentage brought to 56. It is proper to mention here that in this series at least half of the skulls examined were not accompanied by the lower jaw, which if present would doubtless show caries frequently, where it does not occur, in the upper jaw, and raise the average of dental caries in these people to at least 50 per cent, if not higher. Respecting the food of these people the early chroniclers are very explicit and we can not do better than quote Garcilasso de la Vega, who has described it at considerable length. He says: "The maize was the principal food of the Indians." They also ate vegetables of various species which he enumerates and describes. Of their meat diet he says (Bk. VI):

> The common people were in general poor in flocks (except in the Collao where they had plenty), and hence they only ate meat when they received it as a gift from the Curacas, or when, on some great occasion, they killed one of the guinea pigs they bred in their houses, called Ccoz. In order to alleviate this general want the Ynca ordered these hunts to take place, and that the flesh should be distributed among all the people. They made dried meat of it, called "charqui," which kept good until the next hunt; for the Indians were very abstemious and very careful in preserving their dried meat. * * * It would naturally be supposed that as there is so much water there would be plenty of fish; but in reality there is very little. * * * In the great lake of Titicaca, however, there are many fish. * * * There are several kinds of wild bees, but the Indians did not raise them in hives. The bees in temperate and hot climates, enjoying good herbage, make excellent honey, white, clean, and sweet. * * * The Indians value it much not only for eating, but also for several medicinal purposes.

F. de Xeres* tells us:

> The coast people eat flesh and fish all raw, and maize boiled and toasted.*

* Quoted from the Spanish historians in HERBERT SPENCER'S Descriptive Sociology, Division II, Part 1 B—New York (1874?).

We have selected a series of 42 skulls of the so called Mound Builders of the Mississippi Valley. These have been collected for the most part in Illinois, Kentucky, Tennessee, and Wisconsin. Whether or not they represent a homogenous race has not been accurately determined; but it appears to be pretty well established that they lived largely upon the products of the soil of which maize formed the chief staple. It is also probable that they subsisted to a certain extent upon fish and game, but it is believed that they were tillers of the soil rather than hunters. An examination of this series reveals 16, or about 38 per cent, in which caries is present. Of the remaining 26, in 4 cases there was ante-mortem loss with obliteration of the alveoli which, if due to decay, would increase the percentage to about 47.

Passing now to the California Coast Indians we find a people whose diet probably consisted largely of fish, although it is well known that berries, grass seeds, acorns, and various vegetable substances formed a part of their food. In this series of 38 skulls 5, or over 13 per cent, exhibit dental caries.

Of the dwellers of the open plains we include 34 skulls of the Sioux. As is well known these people have lived for many generations upon an almost purely animal diet. The Buffalo, until recently furnished their chief staple of food, very little vegetable substance being consumed. Among this number but 3, nearly 9 per cent, out of 34, show any caries. These skulls were gathered over twenty years ago while game was still abundant in the Sioux country. Those with carious teeth are all from eastern bands who had, even then, begun to use the food of white people to some extent.

Lastly we come to the Alaskan Indians, who were probably the most exclusively carnivorous people in existence except the Eskimo. Out of 42 skulls examined we have failed to find a single case of caries, although abscess and premature loss of teeth are present in 8 cases. We are inclined to believe that abscess and premature loss of teeth is more due to accident and violence than decay. It has often been noted of these people that the teeth are extensively used as a sort of vise for many operations, and it would not be at all surprising if they sustained occasional injuries leading to the formation of abscess and not infrequent loss.

With this evidence before us it can not said that a meat diet is injurious to the teeth or a vegetable diet especially beneficial.

TABLE P.—*Dental caries among different American peoples.*

Peoples.	Total number of skulls examined.	Number showing caries present.	Number showing absence of caries.	Number showing loss with out caries.	Percentage without loss.	Percentage with loss.
Saladoans	35	18	10	7	51.1	71.4
Peruvians	66	29	29	8	43.9	56.0
Mound Builders	42	16	22	4	38.0	47.6
Californians	38	5	33	.....	13.1	.....
Sioux	34	3	31	.....	8.8	.....
Alaskans	42	.....	42	.....	.....	.....

Deformity.—The malposition of the teeth or deformity of the dental arch is of very frequent occurrence in the skulls of the Salado Valley people. Out of 30 skulls it is found to a greater or less extent in 16, making over 53 per cent. If we divide them up into incisor, cuspid, bicuspid, and molar deformities we find that there are nine cases of malposition of the incisors, six in which the cuspids are affected, five of the bicuspids, and three of the molars. There is one interesting case in which the canine of the left side had been displaced outward by the persistence of a milk tooth occupying a position between the lateral incisor and the first bicuspid.

There are many of these cases of deformity associated with caries of the teeth, more especially in those situations favorable to the lodgment of particles of food. Deformity appears to have been a fruitful cause of decay.

Among the Peruvians, out of 65 skulls we are able to find only 7, or nearly 11 per cent, in which there was any deformity of the dental arch. In these skulls the arch is well rounded and the teeth are very regular, resembling in this respect the form of arch displayed by the Alaskans.

Among the Mound Builders, in a series of 41 skulls there are 6, or over 14½ per cent, of which nearly all referred to the incisors.

The series of Californians, 36 in all, exhibit but 4 deformities, or a trifle over 11 per cent.

Among the Sioux there were found 4 deformities of the dental arch in 34 skulls, or over 11½ per cent.

The Alaskan Indians on the other hand display a much higher percentage of deformity; for out of 41 skulls 8 deformities were found, making nearly 20 per cent.

TABLE Q.—*Dental deformity among different American peoples.*

Peoples.	Total number of skulls examined.	Number of skulls showing dental deformity.	Percentage of deformity.
Saladoans	30	16	53.3
Alaskans	41	8	19.5
Mound Builders	41	6	14.6
Sioux	34	4	11.7
Californians	36	4	11.1
Peruvians	65	7	10.9

Tuberculation.—Prof. Cope* has recently called attention to the absence or slight development of the postero-internal tubercle of the second upper molar in certain races. According to his researches the Eskimos generally have but three tubercles upon the grinding surface of the last two superior molars, representing the tritubercular condition, while the Negroes and Malays display four tubercles upon these teeth, which are, therefore, quadritubercular. These differences are marked and very constant in these races and serve to distinguish two extremes of tuberculation. Among the various tribes of American Indians, however, certain intermediate steps are met with, which in the groups considered we have endeavored to represent by percentages.

Upon the first molar there are always four principal tubercles (two external and two internal) and the grinding face of the crown is always square. In the Negro and Malay the second, and not infrequently the third, molars are similarly constituted; but in the Eskimos the second and third molars bear only three principal tubercles, of which two are external and one internal. The internal cusp is large and crescentic in outline and covers the entire internal aspect of the grinding surface; but it sometimes happens that a faint trace of the fourth cusp is present in the form of a slight ledge or cingulum at the postero-internal angle of the crown. Those skulls in which the second molar has its full complement of tubercles we have marked 4; those in which the tooth displays a trace of the fourth cusp we have marked 3½, while those in which there are only three tubercles we have marked 3.

Taking the Alaskans as the extreme of the tri-tubercular type we have in 43 examined skulls 29, or over 67 per cent, in which the second molar bears 3 tubercles; 8 of the 43, or over 18½ per cent, display traces of the fourth cusp, and 6 of the series, or nearly 14 per cent, have the fourth cusp fairly well developed.

Out of a series of 71 skulls of the ancient Californians 44, or nearly 62 per cent, are tritubercular; 15, or about 21 per cent, have traces of the fourth cusp, and 12, or nearly 17 per cent, have all the tubercles developed.

The series showing the next highest percentage of the tri-tubercular type is that of the Mound-Builders, in which out of 37 skulls 15, or 40½ per cent, are tri-tubercular; 4, or nearly 11 per cent, have the tubercles 3½, and 18, or over 48½ per cent, have all the tubercles present.

The condition of the second molar in the Saladoan skulls gives the following results: Out of 23 examples 9, or about 39 per cent, are tritubercular, and the remaining 14, or nearly 61 per cent, are more or less quadritubercular.

Next come the Peruvians, in whom 19 out of 53 skulls, or about 36 per cent, are tri-tubercular, 14 or nearly 26½ per cent have the 3½ tubercle, and 20 or over 37½ per cent are quadri-tubercular.

Lastly we come to the Sioux, of whose skulls 37 are represented in this series. In these 6 or

*Journal of Morphology, Boston, 1888, 1889, Vol. II, pp. 7, etc.

over 16 per cent are tritubercular, 18 or over 48½ per cent have tubercles 3½, and the remaining or slightly over 35 per cent have four tubercles well developed.

From a careful consideration of the facts here set forth it would seem that the nearest allies of the ancient inhabitants of the Salado Valley, if we judge from the prevalence of dental decay, are the Peruvians upon the one hand, in whom caries was almost as frequent, and the Mound Builders of the Mississippi Valley on the other, who also suffered to a considerable extent from tooth-decay. Whether we are to accept the dental condition described as indicating affinity or whether they are to be regarded as the effects of climate, food, and general habits of life we are not prepared to say; but it is more than probable that they have a certain value as expressing race affinity.

The facts relating to the structure of the teeth themselves are important, and we are disposed to attach more weight to them, so far at least as evidence of affinity is concerned, than to the other two classes combined. The high percentage of the tritubercular second molar in the Alaskan Indians, 67 per cent, is significant and betokens either much commingling or a very near relationship with Eskimos. In a like manner the percentage of 62 among the Californians is suggestive of near affinity with the inhabitants of Alaska. The Mound Builders, Salado Valley people, and Peruvians on the other hand are very closely related in this respect, as is indicated by the percentages 40, 39, and 36, while the Sioux stand considerably apart from the rest with a percentage of only 16.

TABLE R.—*Tuberculation among different American peoples.*

Peoples.	Total number of skulls examined.	Number showing 3 tubercles.	Number showing 3½ tubercles.	Number showing 4 tubercles.	Percentage of 3 tubercles.	Percentage of 3½ tubercles.	Percentage of 4 tubercles.
Alaskans	43	29	8	6	67.4	18.6	13.9
Californians	71	44	15	12	61.9	21.1	16.9
Mound Builders	37	15	4	18	40.5	10.8	48.6
Saladoans	23	9	.....	14	39.1	.....	60.8
Peruvians	53	19	14	20	35.8	26.4	37.7
Sioux	37	6	18	13	16.2	48.6	35.1

§ 27. THE HYOID BONE.

[By JACOB L. WORTMAN, M. D., Anatomist of the Army Medical Museum.]

The following study of the human hyoid arch has been undertaken with a view to the determination of the more exact value of this series of bones in matters of anthropological research. The subject has received so little attention at the hands of anatomists, especially from this particular standpoint, that there is little or no literature upon it, and we are as yet in comparative ignorance regarding the conditions and characteristics of this chain of bones, even in the best anatomically known races of mankind.

The history of this undertaking dates from the author's connection with the Hemenway Southwestern Archæological Expedition to the valley of the Salado, Arizona, in 1887, whither he was sent by the United States Army Medical Museum to obtain a full series of skeletons of the ancient dwellers of this region. While engaged in the collection of this material it was noticed that the body or middle piece of the hyoid bone was almost always free, and that the separate pieces, of which the hyoid arch is made up, seldom united into a single bone, even in the most aged individuals. The hyoid, as the writer had been accustomed to see it in skeletons of whites and negroes, consisted usually of a single U-shaped bone, especially if the individual had passed the middle point of life; and upon consulting a few standard text-books on human anatomy which had been taken into the field for ready reference it was found that this was regarded as the usual or normal condition.

The attention of Dr. Herman ten Kate, the anthropologist of the expedition, was called to the subject, and together we took accurate note of the probable ages, conditions of bone disease, etc., of all the individuals whose hyoids were secured. In all there were obtained some 97 speci-

mens of various ages, which are now preserved in the collection of the United States Army Medical Museum at Washington.

Upon our return to Washington we searched the literature carefully for any statement that would throw light upon the subject, but were unable to find that anything had been said or written upon the subject other than the general statements contained in works upon human anatomy. We accordingly prepared a paper setting forth the principal facts, which was presented to and read before the Congress of Americanists held in Berlin.

One of the chief difficulties with which we had to contend in discussing the general bearing and importance of our discoveries was the lack of materials for comparison. Since then the writer has been actively engaged in collecting materials illustrative of the characteristics of the hyoids in the negroes and whites, and he is now in a position to discuss the subject upon a more accurate basis. The sources of materials have been as follows: From Prof. Thomas Dwight, of the Harvard medical school, the Museum has received a record of 33 cases, of which 4 were black, 28 white, and 1 of mixed Mexican and Indian parentage. These specimens were from individuals ranging from 17 to 82 years of age, and include both sexes. From Prof. Towles, of the University of Virginia, the Museum has received 12 specimens of hyoid bones, all from negroes, with the ages attached. From Prof. Matas, of the Tulane University, New Orleans, there are 17 specimens, of which 12 are from negroes, 4 from whites, and 1 from a Chinese. From a personal collection there are 23 specimens, of which 21 are of colored people and 2 are of whites.

What may be considered as a typical hyoid arch of the higher mammalia is to be found in the dog, Fig. 37, which is taken from Prof. Flower's "Osteology of the Mammalia." We prefer to follow this author in the nomenclature of the several elements composing it, which is essentially that proposed by Prof. Owen many years ago. In this we observe first a central unpaired piece or body, which is denominated the "basihyal;" from the outer extremities of this central piece two long slender rods of bone project backwards over the upper edge of the thyroid cartilage and are called the "thyrohyals" or greater cornua. Near the junction of the thyrohyals with the basihyal are attached the distal pieces of two chains of bones which connect the basihyal piece or body with the temporal bones of the skull. The first piece of this series, counting from the basihyal, is the lesser cornu or "ceratohyal"; the second is the "epihyal," the third is the "stylohyal," and the last piece, which finally joins the skull, is that called by Prof. Flower the "tympanohyal."

FIG. 37.—Extracranial portion of hyoidean apparatus of a dog, front view; *sh*, stylohyal; *eh*, epihyal; *ch*, ceratohyal (these three constitute the "anterior cornu"); *bh*, basihyal, or "body" of hyoid; *th*, thyrohyal, or "posterior cornu." [After Flower.]

While this might be called the typical arrangement of the mammalian hyoid apparatus, it so happens that in many forms, including monkeys and man, the complete bony connection between the basihyal and the base of the skull does not exist, owing either to the absence in this chain of bones of certain elements or their rudimentary condition. In this case a ligament may take the place of one or more of these elements, which in human anatomy is known as the stylohyoid ligament.

Prof. Flower, in speaking of the human hyoid apparatus, says:*

> The stylohyal, at first a long styliform piece of cartilage continuous with the tympanohyal, commences to ossify by a separate center before birth, and at a very variable period afterwards is often (but by no means constantly) anchylosed with the tympanohyal and surrounding cranial bones, constituting the so-called "styloid process." This is a condition not met with in any other mammal. Below the stylohyal the greater part of the anterior hyoid arch is represented by a slender ligament (the "styloid" ligament), there being no ossification corresponding to the dog's epihyal.

This view has been generally accepted and it is now commonly taught that the epihyal element of the dog is missing in the human hyoid arch.

A different conclusion upon this important point has been reached by Thomas (de Tours),† who, in speaking of the human hyoid arch, says:

> The body is the strongest piece of the entire apparatus. This is an osseous lamina curved in the form of an arc. Its anterior face, very irregular, is convex from side to side and from above downwards, and is composed of two ob-

* Osteology of the Mammalia, p. 159. † Éléments d'ostéologie, Paris, 1865, p. 219, Pl. x.

lique planes, the one anterior and inferior, and the other superior. The angle at which these unite forms a prominent ridge directed transversely in the sense of the greatest dimension of the bone; the posterior face is profoundly excavated. At each extremity it is articulated with the thyroid cornua. These are two straight bony pieces directed from before backwards and latterly flattened; their posterior extremities give attachment to the thyrohyoid ligament. These pieces unite, forming an arc, to the circumference of which the larynx is suspended, followed by the trachea and lungs.

Each hyoid chain is composed of three pieces, as in the preceding animals (dog and sheep); the first or superior piece has the form of a very elongated cone with its base above and its summit below, its greatest dimension being three centimeters. Its base articulated with the hyoid prolongation gives it a varying length. Its union with this prolongation takes place at different periods, sometimes at thirty years, sometimes at sixty years. This union is to be always recognized by its nodular appearance, more or less distinct.

The second or intermediate piece has nearly the same form as the first, except that it is much more slender; its length is about two centimeters; its base articulating with the summit of the first piece at the middle of the ligament gives it a very variable length. From its summit proceeds the stylohyoid ligament, which terminates in the third piece or small cornu of the hyoid and forms a very acute angle with the greater or thyroid cornu.

This third piece has very often the form and size of a grain of barley, but sometimes it is elongated and styliform, like the intermediate piece. It joins the extremity of the body of the hyoid in such a manner as to form an articulation common to it and the greater cornu. The stylohyoid ligament is composed of whitish glistening fibers possessing great elasticity. It is very slender, tapering in its superior and swelling out in its inferior part, which is attached to the small hyoid cornu.

In the normal condition in man the superior piece of the hyoid chain is united by one extremity to the hyoid prolongation and by the other to the intermediate piece. One then finds the styloid process of authors. This osseous stem, 4 or 5 centimeters long, knotted and sometimes curved and twisted, ends in a point, and in certain subjects descends to the angle of the jaw.

It is this disposition, the union of the two superior pieces between themselves and with the hyoid prolongation to form the styloid process, and the other part, the great distance between the preceding piece, and the third part, a distance traversed by the stylohyoid ligament, which has caused the error of anthropotomists and has led them to divide the hyoidean chain into two parts—the one which has been described with the hyoid, viz, the small cornu or third piece, and the other which has been attributed to the temporal, viz, the styloid process. They might have easily avoided this error by studying comparatively the hyoid apparatus of man and animals. They might have recognized that the styloid process of man represents the stem formed in the ruminant and in the carnivore by the first two pieces of the chain, and that in man the articulation at a long distance of the summit of the styloid process with the lesser cornu corresponds to the disposition of the third much more movable piece, which descends from the rigid rod to suspend the hyoid in animals.

Several authors in works on human anatomy mention the condition described by Thomas: Meckel, in speaking of the temporal bone, says*

The muscular eminences and depressions are, first, the styloid process (*processus styloideus*), at the posterior extremity of the under edge of the pyramid; this varies much in length and sometimes exceeds two. This process is sometimes entirely free and is often composed of several pieces—a curious analogy with animals.

In Gray's Anatomy it is stated:†

The styloid process varies in size and shape and sometimes consists of several pieces united by cartilage.

The writer's experience upon this subject is confined principally to observations upon the adult skull. He has, however, examined a number of fetuses, in which he has always found the styloid process to consist of but a single slender piece of cartilage reaching from the temporal towards the basihyal. It is highly probable that the failure to find the several elements described was due to the age of the specimens examined, all of which were at or before full term.

The most favorable age to select is somewhere between the time when ossification begins and twenty-five or thirty years. Unfortunately, in the average museum specimen of this age the styloid process has not been preserved, and all that one can discover is a short peg of bone wedged in between the two laminæ of the vaginal process. In skulls of more advanced age, wherein the several pieces have not only united with the skull but have been joined to each other, it is not an easy matter always to determine the point of union.

In a large series of skulls in the collection of the Army Medical Museum the following is the most common condition: A short distance below or quite at the edge of the vaginal process there is a considerable swelling or nodosity, and if the subject be not too old the remains of a suture are discoverable at this point. Sometimes this nodosity is placed as much as a half an inch below the

* J. F. Meckel, Manual of Descriptive Anatomy (English Translation), London, 1838, Vol. i, p. 57.

† Gray's Anatomy, 1887, p. 144.

edge of the vaginal process and sometimes quite within its folds. Below this nodosity there can sometimes be seen a second swelling with the same evidences of a suture. Then, again, there are many skulls in which the first nodosity is present, and the process is terminated by a truncated extremity, as if a piece had been attached to it, but had been lost in preparation; and, finally, in some few cases the styloid composed of three distinct pieces was observed, as described by Thomas.

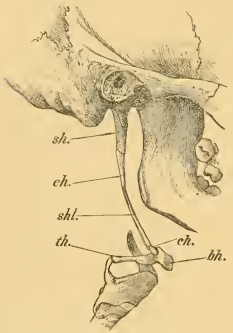


FIG. 38.—Hyoidean apparatus of man. [After Thomas.]

There can be little doubt that the part spoken of by Thomas as the "hyoid prolongation" is the tympanohyal element of Flower, which, there is good reason to believe, is variable in length. There is also little doubt that not uncommonly there is a distinct ossification intervening between the lower end of the true stylohyal element and the ceratohyal piece, or small cornu of the hyoid, which can not be accounted for upon any hypothesis other than that it is the strict homologue of the missing epihyal so constant in the lower forms. It would be a matter of no little interest to determine the frequency of its occurrence in the various races of mankind. (See Figs. 38 and 39.)

Passing now to the hyoid bone proper, we have to consider the several elements of which it is composed. As is well known, it is generally described in works on human anatomy as consisting of a single U-shaped bone, formed by the union of five pieces. These are known as the body and the greater and lesser cornua. Although there does not appear to be absolute unanimity of opinion among anatomical writers regarding the particular time of life when these elements coössify, we can not do better than to quote here the statements made by the leading anatomical authorities upon this point.

Among the German anatomists Meckel, in his *Manual of Anatomy*, says:

"The hyoid bones, or the hyoid bone, forms an arch which is convex forwards. It is situated behind and below he maxillary, beneath the root of the tongue and the upper part of the neck. It is generally considered a single bone, and is divided into a central portion, or body and four horns, two upon each side; but as these parts remain distinct throughout life it is better to admit five distinct bones, a middle and four lateral. The inferior hyoid bones, or the greater cornua of the hyoid, often vary considerably in form and size upon the different sides in the same subject. They articulate with the central piece by a fibro-cartilaginous mass and sometimes unite in the latter periods of life in one bone."

FIG. 39.—Styloid process of man. [After Thomas.]

Heule, in his *Human Anatomy*, says:

"The great horns of the hyoid bone can also be connected with the body by joint. Many hold this to be the rule."

Hyrtle, in his *Lehrbuch der Anatomie des Menschen*, says, quoting from Meckel:

"The os hyoid is divided into central or body and two lateral cornua, which parts, as they are united by movable articulation or by synchondrosis, and often in old age not coössified, can be considered as so many different or separate hyoids."

Gegenbaur, in his *Lehrbuch der Anatomie des Menschen*, says:

"The great cornua often coössify with the body."

Hartmann, in his *Handbuch der Anatomie des Menschen*, says:

"The five parts of the hyoid bone articulate by movable joint at the small horns and with synchondrosis at the large horns. In old age these parts are ofttimes anchylosed."

Krause, in his *Menschliche Anatomie*, says:

"The great horns are united with the body by capsular ligament, and the joint is an amphiarthrosis. Very often it is only a synchondrosis."

Walter, *Human Osteology*, Berlin, 1798, says:

"It is rare that the entire bone is ossified. It occurs only in very advanced age."

The conclusion which one draws from these statements is that the great cornua of the hyoid bone remain free even in old age in the majority of examples upon which these observations have been made, and all these authorities seem to agree that it is only at a very advanced period of life that any of the hyoidean elements coössify. Taking for granted that the observations of German anatomists have been made upon German materials for the most part, one can safely say, if these statements be correct, that this is the normal condition of the German hyoid.

French anatomists make a different statement. Sappey, in his *Traité d'anatomie descriptive*, 1867–'72, says:

"At 40 or 50 years, ofttimes before that period, the great cornua are joined to the body. The little horns are also sometimes joined to the body, but only in old age."

Boyer, *Traité d'anatomie*, 1803–'9, says:

"With age the great cornua are joined to the body. The small cornua also unite, but this happens much later."

Cruveilhier, *Anatomie descriptive*, 1844, says:

"All the pieces are at first separated by considerable portions of cartilage, afterwards by a very thin layer, which sometimes remains during life."

Portal, *Cours d'anatomie médicale*, 1803, says:

"The borders of the body and the middle of the greater horns ossify first, but they remain epiphyses for a long time, or separated from the body of the bone by a portion not ossified, and which hardens with age. The small cornua remain still longer without ossifying; but in old age not only are all the pieces of the hyoid united, but the stylohyoid ligament is ossified."

Beaunis and Bouchard, Nouveaux *Éléments d'anatomie descriptive*, 1873, say:

"The great cornua are sometimes united to the body by a true movable articulation. The small cornua are habitually movable upon the rest of the bone."

One would be led to infer from these statements that the normal condition of the French hyoid, allowing that the observations of the French anatomists have been made upon French subjects, is the complete consolidation of all the five elements and, if Sappey's statement can be trusted, at a comparatively early period of life, so far at least as the great cornua are concerned.

It is a difficult matter to reconcile these statements of the French and German anatomists otherwise than upon the ground of difference in the structure of the hyoid itself in these two peoples. It would be interesting to determine the truth or falsity of this supposition.

English anatomists agree more nearly with the French in their statements of the hyoidean pieces. Flower, in his *Osteology of the Mammalia*, 1870, says of the human hyoid:

"The thyrohyals or great cornua of the hyoid bone are elongated, nearly straight, and somewhat compressed. They usually become anchylosed before middle life with the outer extremity of the basihyal."

Holden, *Human Osteology*, 1885, says:

"Until the middle period of life the great cornua are united to the body by cartilage, but this ossifies in the progress of age."

H. Hyde Salter, in *Todd's Cyclopædia of Anatomy and Physiology*, article, "Tongues," says:

"Ossification begins in the greater cornua; it then takes place in the body, where it begins soon after birth, and finally in the lesser cornua, where it does not commence until some time after. It proceeds but slowly, and generally leaves a thin lamina of cartilage unossified, so that complete anchylosis into one bone is comparatively rare."

Erasmus Wilson, *Human Anatomy*, 1859, says:

"In early age and in the adult the cornua are connected with the body by cartilaginous surfaces and ligamentous fibres, but in old age they become united by bone."

In Gray's *Anatomy* it is stated:

"In youth the cornua are connected to the body by cartilaginous surfaces and held together by ligaments; in middle life the body and greater cornua usually become joined, and in old age all the segments are united together, forming a single bone."

Morton, *Human Anatomy*, 1849, says:

"The cornua are connected to the body by a distinct movable articulation, which generally, however, becomes anchylosed later in life."

Just how far the statement of any of the preceding authorities is the result of individual knowledge and experience, or to what extent the information was drawn from previous authors, or the number of cases upon which the observations were made, does not appear, and for this reason the exact anthropological value of the statements is difficult to estimate. In order to reach the question in a more definite manner we give the results of an examination of 32 specimens of hyoids from whites whose ages are known. For this series the lowest limit in age taken is 35 years, which, although somewhat below the middle point of life, will yet be more nearly comparable to the series of the Saladoans and the negroes which will be referred to later.

The sexes from which the specimens were taken are about equally represented; but the nationality is not given further than that they were white. Of these 21 show bony union of the greater cornua with the body, and in 11 the cornua are free, giving a percentage of 65 and a fraction for those that are joined. For 24 of the specimens the age given is 45 years and upward, and of these 18 are joined and six are free, making a percentage of 75. A more detailed analysis of the union and non-union is as follows: United upon both sides, 17; united upon the left side, 3; united upon the right side, 1; both cornua free, 11. It may be remarked that in the remaining five specimens under 35 years of age there is one (age 31) which shows union of one of the greater cornua, namely, upon the left side. If this was added to the list the percentage would be increased to 66 and over. However, the percentage of 65 may be regarded as a fair expression of the condition of the hyoid of the white so far as the bony union of the greater cornua is concerned. In those of 45 years and upwards 75 per cent is probably a fair estimate of this condition.

Turning now to the negro, we have altogether a series of 35 hyoids which pertain to persons of 35 years and upward. Of these 27 show bony union of the greater cornua with the body and 8 are free, giving a percentage of 77 and over; 21 are joined upon both sides; 3 are joined upon the left side; 3 are joined upon the right side, and 8 are entirely free. We have previously reported upon a series of 25 negro hyoids,* in which the percentage of bony union of the greater cornua was found to be 66. If now we include these 35, we have a series of 60 specimens in which the mean percentage is 70. Of the 35 there are 12 of 45 years and upward, of which 10 are joined and 2 are free, giving 83⅓ per cent. This examination does not take into consideration those cases of mixed blood, since some of the specimens are known to be from mulattoes. Just how this has influenced the percentage is not easy to determine, but it is no more than reasonable to suppose that it has had some effect, and may account in a measure for the close correspondence between the white and the negro in the matter of union of the greater cornua.

In the light of these facts we come lastly to consider the hyoids of the ancient Saladoans, of which there are 97 in all, many of them being complete. Some of this number are not accompanied by the skeletons to which they belong, owing to the advanced stage of decay in which they were found rendering their preservation impossible. In all cases where the skull could not be preserved a careful examination was made with a view to the determination of the age from the condition of the teeth, the synostosis of the sutures of the skull, and the angle of the jaw.

We have adopted the system of labeling them Young, Adult, Old, and Very Old. In the category of "Young" we have placed all those specimens under the age of 21 years, or those in which the last molar had not been erupted, the teeth themselves little worn, and the evidence of epiphyses had not yet been obliterated. In the class "Adult" we have placed all examples in which the teeth were fully erupted and all evidence of epiphyses obliterated, but which do not show any bony union of the cranial sutures. In the class "Old" we have placed all those in which the teeth are very considerably worn and the sagittal or coronal suture shows bony union. The class marked "Very Old" we have made to include all those specimens in which the sagittal, coronal, and lambdoidal sutures were synostosed, in which the teeth were entirely gone—their alveoli being absorbed—or were reduced to inconsiderable stubs, and the angle at which the horizontal ramus of the lower jaw joins the perpendicular portion was very open or obtuse. In most of the examples of this class all the sutures of the skull had disappeared, indicating great age.

That part of our material in which the greatest amount of interest centers is, of course, in the classes marked "Old" and "Very Old," and it is more than possible that a certain number of

* American Anthropologist.

anomalies in the prematnre union of the cranial sutures, as well as the loss of the teeth and the absorption of the alveoli, exist; but we are persuaded to believe that the series is a fairly typical one and exhibits the normal condition of this race in these particulars.

It may be urged that the determination of age upon the basis which we have adopted is not sufficiently accurate for purposes of this kind; but there are few anatomists who would hesitate to pronounce judgment upon the age of a skull from the evidences which we have cited. At all events, we feel that we are entirely within the bounds of reasonable judgment when we say that the classes "Old" and "Very Old" pertain to individuals not under 35 years of age.

Of the class "Very Old" there are 13 examples of the hyoid, in which union of the great cornua with the body is found in 3. In these 3 cases the union is partial, for it is only upon the left side that it exists. It should be stated that in 1 other of these 13 cases the hyoid is represented by one of the great cornua only, so that it is impossible to say whether partial union existed or not upon the opposite side in the case.

Of the class "Old" we have 44 specimens in which bony union of the great cornua with the body of the hyoid exists on both sides in 2, on the left side in 1, and on the right side in 1, making 4 in all. Of these examples 9 are represented by one of the great cornua only, so that it is impossible to say whether partial bony union existed upon the opposite side or not. In all the 4 cases in which partial or complete bony union is found we have discovered skeletal disturbances in the way of exostoses, unusual anchylosis, etc., which would naturally lead to the belief that the union of the hyoid elements was an abnormal condition as well. Be this as it may, however, it will be seen that the percentage of union is very small. Taking both classes in which there are 7 cöossifications in 57 specimens, we have a percentage of only over 12 as against 65 and 77 of the white and negro, respectively.

This difference is marked, and in our judgment can not be accounted for upon any other hypothesis than that of a natural anatomical distinction which these people possess. In the paper which Dr. ten Kate and the writer prepared upon this material we stated at that time—

> That owing to the lack of materials for proper comparison we are unable to make any satisfactory deduction respecting the hyoid at this particular time, and what we here note must be regarded as merely a statement of fact to be correlated in its proper place. * * If, on the other hand, we are to accept the statements of many of the anatomists we have already quoted, then we can say that the very high percentage of free hyoidean elements which we have found in these ancient people distinguishes them markedly from some other races. If, again, it is found that this condition of the hyoid is general in North American Indians, as well perhaps as some other races, it would be interesting to know in what way, if any, it is associated with their language.

These surmises were probably correct, and there appear to be marked distinctions between the hyoidean apparatus of these ancient Saladoans on the one hand and the whites and negroes on the other, a distinction which is indicated by the percentages already set forth.

In a series of 17 specimens recently received from the ancient cemeteries in the vicinity of Zuñi, New Mexico, there are 4 showing bony union of the great cornua and 13 are free. A careful inspection of the skeletons to which they belong gives an indication of age from at least 35 years and upwards. The percentage in this case is 23 and a little over.

From a few specimens (9 in all) of hyoids of the so-called Mound Builders there are 4 cöossifications, giving a percentage of 44 and a fraction; but this series is too small to be of much value to us.

Regarding the lesser cornua we have not devoted that attention to them that we have given to the greater cornua and body of the hyoid: but if we are to judge from what Prof. Thomas Dwight, of the Harvard Medical School, says, it would seem that they may be entirely absent. In a letter transmitting the record of observations given above, he writes:

> The result of the examination of the lesser horns is rather surprising, as it shows that they are very rarely united to the body of the bone, that the mode of connection with the body varies, and that one or both may be entirely wanting. In only one of the 33 hyoids were both lesser horns cöossified, and in only 4 others was a single horn thus united. It is generally taught that the joint between the body and lesser horn is synovial. This is certainly true in many cases but not in all. Sometimes the lesser horn is attached by ligament, and at least in one case I have found it held by muscular fibers. In other cases, owing chiefly to the parts having become dry, it was impossible to decide whether this was a true synovial joint or not. In several cases one or both the lesser horns were not found, and it was not always possible to determine whether the absent piece had been lost or had never existed. It was, however,

shown beyond question that one or both of these horns may be wanting. One was wanting in a girl of 17 and both in a man of 55. In a woman, said to be 80, one was wanting and the other probably wanting. In a man of 37 and another of 39 one was probably wanting. In a woman 50 and a man 55 both were probably wanting. When a joint was found upon the body it was clear that the lesser horns had been lost, which occurred two or three times; but the absence of a joint does not show beyond question that the horn was wanting as it may have been held by ligament. It is thought most probable that where the entry has been made "lost or wanting," the bone was originally wanting.

We come now to consider the body of the hyoid bone, and we regret to say that the soft parts, particularly the larynx, could not be included in this study since our material refers almost exclusively to the dry bone itself. The body of the hyoid in monkeys has a distinctive and characteristic form, which according to Flower* has a greater vertical than transverse diameter (see figs. 40 and 41). This form of the hyoid body is associated in many of the lower types of monkeys with a membranous sack which occupies the concavity of the bone and protrudes between the lower edge of the body and the upper edge of the thyroid cartilage. It was called the hyothyroidean sac by Cuvier, and the *succus membranaceus* by Wolf. It has an opening at the base of the epiglottis and is said to sometimes communicate with the laryngeal sac which lies just above the vocal chords. According to Eckhard,† this hyothyroidean sac is absent in the anthropoid apes, with the possible exception of the gibbon. We are not sufficiently familiar with the anatomy of the larynx of the anthropoids to state whether any rudiment of this condition is to be found in them; but it would not be at all surprising if this eventually turns out to be the case. We are led to infer that the true significance of the great depth of the body of the hyoid in the monkey is to be explained primarily upon the basis of this sac, whatever its function may be, and that the depth of the body in proportion to its width furnishes an index of this distinctively simian feature, which we propose to call the basihyal index.

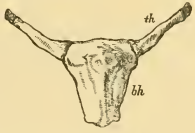


FIG. 40.—Hyoid of baboon; *bh*, basihyal; *th*, thyrohyal. [After Flower.]

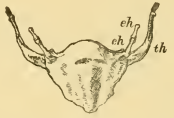


FIG. 41.—Hyoid of an American monkey; *th*, thyrohyal; *eh*, ceratohyal; *ch*, epihyal. [After Flower.]

It is therefore with no small amount of interest that we come to examine this question in the light of our present material. We have been necessarily compelled to limit our researches to the Negro and Saladoan, for the reason that our materials have proven insufficient as regards other races, which are therefore not included. Some difficulty has been experienced in determining just where the measurements should be taken in case the greater cornua are coössified with the body, which is, as we have seen, the usual condition of the adult Negro hyoid. After careful attention to this point we have determined upon the following measurements: The vertical depth is obtained by placing the bone flatwise upon its posterior surface and measuring with a pair of calipers or other suitable instrument its greatest diameter in this direction. The transverse diameter is taken by placing one arm of the dividers upon the point of union of the anterior ridge with the lingual or superior border and measuring to the corresponding point upon the opposite side. In some instances the anterior transverse ridge is not well defined and the point where it terminates is not easily made out. In such cases, if there remain any traces of the suture joining the great cornua with the body we measure from this suture where it crosses the superior border to the same point upon the opposite side.

Among the Saladoans the bodies are mostly free and we have had little difficulty in determining the proportion of the depth to the width. In one instance we measured the greatest diameters and found that the proportion of the depth to the width is 52 per cent and a fraction in 45 specimens. In the same series measured between the points indicated above for the transverse diameter the proportion is 54 per cent.

* FLOWER: Osteology of the Mammalia, p. 140.

† MÜLLER: Archiv für Anatomie and Physiologie, 1847, p. 44.

In a series of 36 negroes the proportion of the depth to the width is 65 per cent and a fraction, or between 11 and 12 per cent more simian. In one case (Fig. 42) the proportion goes as high as 90 per cent, while 75 per cent is not at all unusual in the series.

In the few specimens of the white hyoids which we have the proportion seems to be about 50 per cent, although we have not been able to determine this with any degree of exactness. (See Fig. 43.)

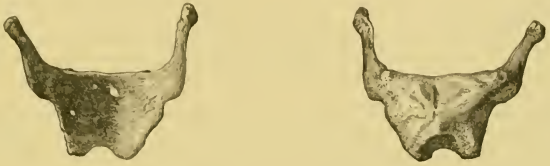


FIG. 42.—Anterior and Posterior views of negro hyoid.

In conclusion we will say that in the present state of our knowledge it is well-nigh impossible to give any intelligent explanation of the facts which have been set forth above, with the possible exception that the greater basihyal index of the Negro is to be accounted for on the basis of his nearer relationship to the monkey. Regarding the coössification of the greater cornua with the body little can be said, but it might be suggested that, since the chief function of the hyoidean appa-

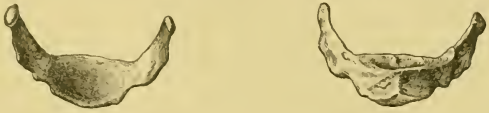


FIG. 43.—Anterior and Posterior views of European hyoid.

ratus is the support of the muscles of the tongue, one would be led to infer that it has something to do with language. It is supposable that in those races where rapid talking and much talking was the rule the hyoidean elements would coössify early, while among those people who speak slowly, deliberately, and comparatively little, the hyoidean elements would unite late in life, if at all. The complexity and modification of sounds depending largely upon the use of the tongue would also furnish sufficient reasons for early or late coössification.

§ 28. INDICES OF THE LONG BONES.

The indices of the long bones (Table LI) which have been taken are the antibrachial and the tibio-femoral. The measurements from which these were computed have been taken by means of the *planche osteométrique* in use in France and according to the directions given by Topinard.* These directions require that all the bones except the tibia shall be so measured as to obtain their maximum length. The tibia is measured from the superior articular surface to the internal malleolus; thus the length of the intercondylar spine for the insertion of the cruciform ligaments is subtracted. The measurements have been taken with great care and are correct to a millimeter.

The indices are reckoned by means of the following formulæ: For the antibrachial index the length of the radius is multiplied by 100 and the product divided by the length of the humerus; for the tibio-femoral the length of the tibia is multiplied by 100 and the product is divided by the length of the femur.

Very few of the skeletons have complete sets of long bones. In many cases only one remains whole. Therefore, in order to obtain the greatest possible results, we have adopted the following plan:

Method I. We compute the indices from bones belonging to the same limb of the same skeleton.

* TOPINARD, *op. cit.*, p. 1033.

Method II. Not having in a given case the material to do this, owing to the absence of one of the necessary bones, we use the calculated *average* length of the missing bone in place of the factor which the peculiar length of it would constitute if it were present. For instance, suppose we desire to calculate the antibrachial index for a limb of which the radius is missing, we multiply the average length of all the radii by 100 and divide the product by the length of the humerus; and if the humerus, instead of the radius, is missing, we multiply the length of the radius by 100 and divide the product by the average length of the humeri. Relatively corresponding formulæ are used for the posterior limb.

Thus we obtain two sets of figures, one which definitely states the relations of the bones in a given individual to whose skeleton both bones belonged, and one which states that a bone of a certain individual bears such and such a relation to the general average of certain related bones, whatever they may be, of his race.

In the synopsis (Table LII) giving the average osteometric indices the results obtained from the complete limbs by method I are given first, then those obtained by method II, namely, by the lengths of the bones compared to the averages. These two groups of figures, which sum up with very little difference, are then combined to give a general average for the race. In each of these groups of indices there are three subdivisions, one for the right side, one for the left, and one for the total of both sides. The figures found at the bottoms of the columns of individual indices are the totals obtained from both methods. They reappear in the synopsis.

The extremes of the indices obtained by method II are preposterous and should be allowed no weight in discussing the variations in relative length of the segments of the limbs. The cause of the great variation in question is almost self-evident. They are from those cases where the individual was much above or much below the normal stature of the race. The cases where the index upon one side of a skeleton is calculated from two of its own proper bones, while upon the other side it is calculated from the relation of a bone's length to the average, often gives a startling difference between the right index and the left index, for which the above explanation accounts; but when we come to the average indices all these difficulties disappear and the figures obtained by method II come close to those obtained by method I. This we regard as sufficient justification for the adoption of method II as a means of increasing the number of individuals with whom our figures deal.

The reader is liable to think that he finds some obscurity with regard to the number of individuals concerned in the combined right and left or total index obtained by method II, and the same index obtained by methods I and II combined. Taking the antibrachial index as an instance, however (see *Synopsis of Indices*, Table LII), the cross line beginning with the words "computed by method II" and giving the number of total indices as 15 must not be read as if it ought to mean that there are 15 indices of each side combined to form a total of 15 indices of both sides but that the index derived from combining the aggregate of each side represents the average of a sum which consists of 30 factors.

A reference to the tables of antibrachial and tibio-femoral indices in Topinard's Anthropology* will show that the variation per cent of these indices is small. His minimum and maximum of the antibrachial index are 69.8 in a male Eskimo and 81.7 in a female Andamanese, respectively; hence only 11.9 per cent—this, be it noted, between individuals, not between racial averages. The tibio-femoral index varies from 78.6 in 9 male Esthonians to 89.0 in 1 female Negrito, or 10.4 per cent.

The maximum and minimum of series which contain five or more (individuals or limbs?)† are as follows: For the antibrachial index the maximum is 79.0 in 32 male African Negroes, the minimum is 72.4 in 26 female Europeans. For the tibio-femoral index the maximum is 84.4 in 10 African Negresses, the minimum is 80.2 in 5 male Chinese.

Continuing our study of Dr. Topinard's tables, we find that the sexual differences with regard to these indices are not great. As to the antibrachial index, the sexual difference ranges from 0.1 in Europeans to 3.0 in South Americans, the males having the higher index in each case. As to the tibio-femoral index, the sexual difference ranges from 0.3 in Europeans to 1.5 in negroes, the

* Topinard, *op. cit.*, pp. 1043–1045.

† Probably individuals. (See Topinard, *op. cit.*, pp. 1043–1045.)

males having the higher index in the first case and the females in the second. We believe, therefore, that the sexual difference is not sufficient to impair the value of the averages derived while combining the sexes from a relatively large series. Hence we do not state the sexes upon our tables. Indeed it is less our policy to investigate the sexual and other intraracial characteristics of this people than to accumulate facts and distinctions dealing with their place in the human series.

The relation between the antibrachial index and the tibio-femoral index, as shown by Dr. Topinard's tables, may be, if we are permitted to borrow a term from craniology, *harmonic* or *disharmonic*. Thus both indices may be large or small; in that case the relation is harmonic, or one may be large and the other small; in this case the relation is disharmonic. Harmonic indices are the rule. Topinard calls attention to disharmonic indices in saying:

> The Chinese, who have an elevated antibrachial index, have a low tibio-femoral index. The Bushmen, who have a low antibrachial index, have a relatively elevated tibio-femoral index.

We give (Table LIII) those of Dr. Topinard's figures, which deal with 5 or more cases, for comparative data. His own comment upon them that they "rest upon too few cases" should, however, be borne in mind.

It is considered by comparative anatomists that increasing length of the second segment of a limb as compared with the first segment is, when found in man, a low character. This opinion is grounded upon the knowledge of the relatively great length which the radii and tibiæ of anthropoid apes bear, respectively, to the humeri and femora. The criterion thus established places the Saladoans well toward the foot of the human scale. With regard to the antibrachial index they stand next to the bottom of the scale, between the Chinese, Annamites and Javanese above and the African negroes below, and removed three places, or 2.72 per cent, from the South Americans. With regard to the tibio-femoral index they stand at the bottom of the scale, next below the South Americans. These latter, therefore, we note in passing, seem to have quite disharmonic indices of the long bones, which the Saladoans certainly have not.

As will be seen from a glance at Table LIII, where we give extracts from Topinard's figures and insert our own data for the Saladoans in their proper places, the characters derived from the study of the long bones must be called discordant or "out of the series" by those anthropologists who insist that all data of a true scientific value shall group themselves in a scale having a European at the top, a Chinaman in the middle, and a Negrito at the bottom.

§ 29. THE SCAPULAR INDEX.

Owing to the greatly damaged condition of the skeletons, only fifteen adult scapulæ were in a sufficiently good state of preservation to be submitted to the measurements of length and width required for computing the scapular index. Of these, nine are right scapulæ and six are left scapulæ. The maximum index is 81.66; the minimum, 65.21, both found on the right side. The average for the right scapulæ is 71.42, and for the left 70.61. The general average is, then, 71.09 for the whole series.

Here again we find the Saladoans occupying a low position in the human series.

The following extract from Flower and Garson's* figures on the subject exhibit the position of the Saladoans, whose index we insert with reference to certain other peoples.

Races.	Indices.
6 Tasmanian scapulæ	60.3
200 European scapulæ	65.2
6 Bushmen scapulæ	66.7
12 Australian scapulæ	68.9
21 Andaman scapulæ	69.8
15 Saladoan scapulæ	71.0
6 Negro scapulæ	71.7

But it is probable that the distinctive numerical grades of value of the scapular index differ from one another by so small degrees that large series must be measured in order to obtain figures

* FLOWER and GARSON: On the scapular index as a race character in man. Journal of Anatomy and Physiology, London, 1879.

sufficiently valuable to justify a conclusion. Indeed, if we rightly interpret the spirit of previous writers upon the subject, we should be inclined to believe that the series of Europeans given above is the only series large enough to be of undoubted value.

Broca* says:

* * * There is but a very slight difference between the human average and the averages of the great anthropoids, a difference so feeble that it disappears often when one considers, instead of the averages, the individual cases.

§ 30. TORSION OF THE HUMERUS.

Notwithstanding the opinion of Topinard, that the angle of torsion of the humerus gives "a good zoölogic character and a bad anthropologic character,"† we have determined it in all the humeri of this collection (41 in number), in which the necessary guiding marks as laid down by Broca‡ were found intact. Of this number 21 were from the right side and 20 from the left; but there were only 15 complete pairs. Of the latter 6 pertained to female skeletons, 5 to male skeletons, and 4 to skeletons of undetermined sex. Of 6 right unpaired humeri 2 were male and 4 of undetermined sex. Of 5 left unpaired humeri 1 was male and 4 of undetermined sex.

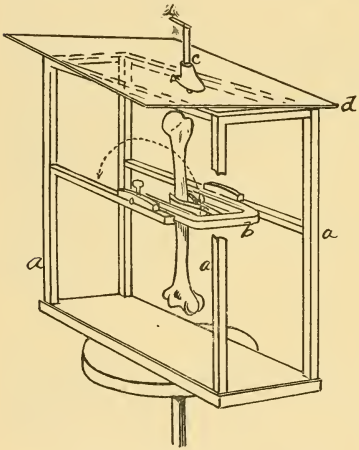


FIG. 44.—Apparatus for determining torsion of the humerus.

The degree of torsion was ascertained by a graphic system analogous to that employed by Lucae and Welcker,§ but by means of an apparatus different to theirs, which was devised by Dr. J. C. McConnell, of the Army Medical Museum, and is shown in Fig. 44.

It is a modification of the apparatus mentioned in § 3 and illustrated in Fig. 23. The periglyph (Fig. 24) is employed and the tracings are taken on varnished glass, inked and transferred to paper in the manner described in § 3. The frame (*a*, *a*, *a*) is much the same in both apparatus; but in the one now under consideration we have in the center of the frame a revolving stage with a clamp for holding the humerus.

Four long distinct parallel lines are drawn on the stage at right angles with its axis—one on each side of the clamp—on both the upper and lower surfaces, those on one surface being exactly vertical to those on the other.

The angle of torsion is obtained in the following manner: Indicate on the humerus the axial lines of its two extremities. Secure the bone in a vertical position at the middle of the shaft by means of the clamp, let us say with the head of the humerus upwards at first; make a tracing of the head by means of the periglyph (*c*) on the varnished glass (*d*), being careful to include a tracing of the axial line and the parallel lines drawn on the stage. Invert the stage by turning it on its axle, inverting at the same time the bone and bringing the lower surface close to the varnished glass, where the outline with the axial and parallel lines may be sketched with the periglyph as before; ink the tracings and transfer to the paper in the manner described in § 3.

* P. BROCA: Indices de Largeur de l'omoplate. Bulletins de la Société d'Anthropologie, Paris, 1878, p. 77.

† *Op. cit.*, p. 1048.

‡ La torsion de l'humerus. Revue d'Anthropologie, Paris, 1881. T. 2 serie, pp. 389 *et seq.*

§ LUCAE: Die Stellung des Humeruskopfes zum Ellenbogengelenk beim Europäer and Neger, in Archiv für Anthropologie, 1866, I, p. 237 *et seq.*

In making the transfers to paper superimpose one sketch on the other in such a way that the axial lines shall cross or touch, and the parallel lines shall exactly coincide. Apply the protractor and read off the angle of torsion.*

In every case where we have applied this method we have, as a matter of record and identification, drawn the outlines of the extremities, an easy task; but it would have been sufficient to draw only the axial and parallel lines.

Figure 45 shows the character of the tracing. The outline of the head is broadened in order to distinguish it more plainly from that of the opposite extremity.

The general results of our measurements are shown in Tables LV to LVIII, inclusive, and in diagram shown below. Tables LIX and LX give the angles of other humeri in our Museum. A number of tables prepared by Broca and Manouvrier have been consulted which, though the measurements were taken by a different process, will, we believe, admit of comparison with our results. From all these sources the following facts are collated:

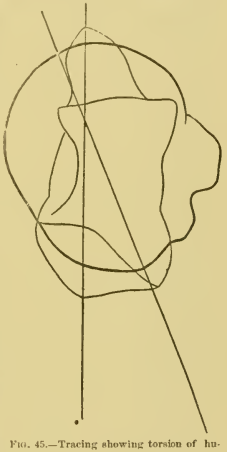


FIG. 45.—Tracing showing torsion of humerus.

A statement of Broca's,† based upon abundant data, is that the average torsion is greater in females than in males, and his Table D shows that not only in the general average, but that in the average for each side the female exceeds the male, there being but one insignificant exception in the series of Californians. In this respect the Saladoans seem to be at variance with the rest of the human race. In Table LVIII it will be observed that humeral torsion in the males is greater on both sides, and therefore greater in the total average, than it is in the females.

Another conclusion of Broca's‡ is that in nearly all the series (studied by him) the left humerus is, on an average, more twisted than the right; such, too, is the evidence of our general collection (Table LX) even with regard to American races. In the Salado skeletons, on the contrary, the average is almost the same on both sides, that of the right being slightly in excess of that of the left. Among the humeri in pairs, also, there is a slight excess on the right side. The variation, too, is greater on the right than on the left side in this series, the former showing both higher and lower angles than the latter.

In 75.8 per cent of Broca's series the maximum of torsion is on the left side.§ Here again the Salado series ranges itself with the small minority. Not only the maximum but the highest three angles are found on the right side. It belongs to the majority, however, with regard to the minimum, which is on the right side as in 72.4 per cent of Broca's series.

In comparing the humeri of this series (Table LV) with those of our general series (Table LIX) we discover that three angles of the former (177°, 174°, 174°, all dexter) are higher than the maximum of any other race except the French, and that they are higher than several of the French angles. If we study this series in connection with Broca's Table C,‖ in which is given a list of 29 series, comprising the most varied races in the world, the maximum angle of the Saladoans would still seem to have the same relative importance—standing next to the French.

The average torsion of the left humerus (159° 30′), the average of the right humerus (159° 45′), and the average of all the humeri (159° 30′+) are higher than the corresponding averages in any series (representing more than one individual) of our collection except the French and Lapps.

* Journal of Anatomy and Physiology, vol. XXI, p. 536.

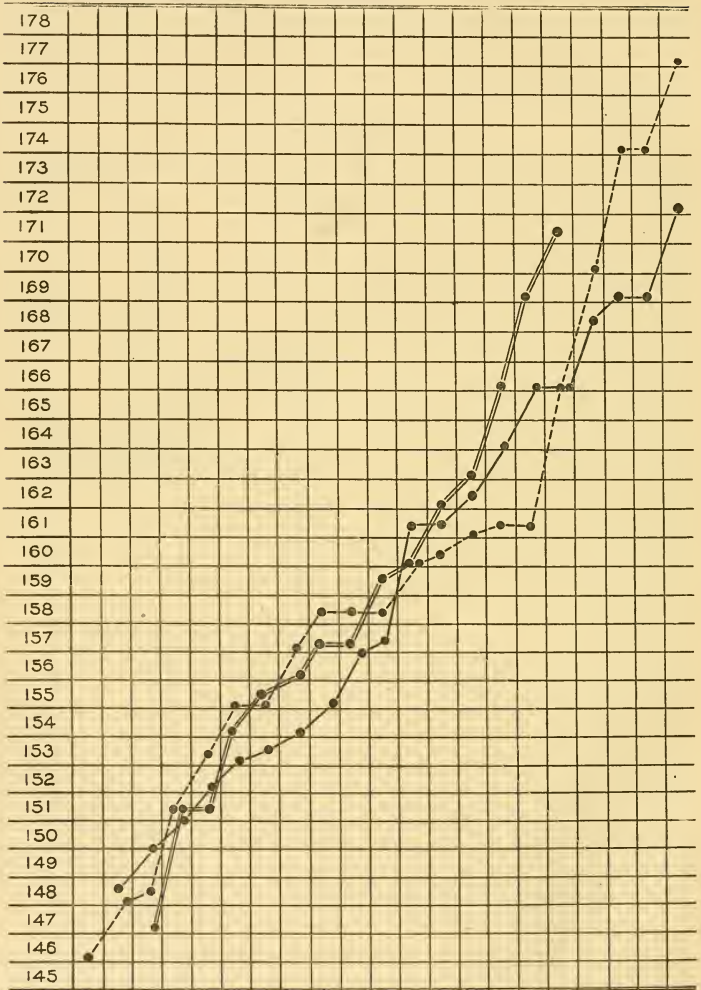
† La torsion de l'humérus. Revue d'Anthropologie, 2e Série, T. 10, Paris, 1881; pp. 577 *et seq.*

‡ *Loc. cit.*, p. 583.

§ *Loc. cit.*, p. 584.

‖ *Loc. cit.*, p. 583.

Diagram showing the difference between angles of torsion of right and left humeri.



Dotted line = right; single line = left; double line = both.

They are also higher than any of the averages in Broca's Table B,* except the modern Europeans and some of the ancient Parisians. They are higher than those of the French of the Polished Stone period. This Table B of Broca's shows 29 series, representing the most diverse races of the world, and is therefore an excellent basis for comparison.

§ 31. THE OLECRANON PERFORATION.

In the prevalence of the olecranon perforation the ancient inhabitants of the Salt River Valley stand, so far as we can learn, at the head of the human race. The following table shows the percentage of this anomaly in 24 series, of more than 15 humeri each, representing many different races and periods of time and arranged in order from the highest to the lowest percentage. It will be seen that the ancient Saladoans stand easily at the head of the list. We might have enlarged this table from our researches into the literature of the subject and by including smaller series, and yet have given no race precedence over the Saladoans.

TABLE S.—*Showing percentages of olecranon perforation in different peoples.*

Number of humeri.	Number of foramina.	Per cent.	Authority or collection.	Race or source.
89	48	53.9	U. S. Army Medical Museum	Ancient Saladoans (Hemenway collection).
150	69	46	Bulletins de la Société d'Anthropologie. Paris, 1878, Vol. 1, p. 433.	Guanches, Canary Islands (Verneau).
30	.....	36.2	Topinard, Éléments d'Anthropologie Générale, p. 1016.	Yellow and American races.
32	.....	34.3	.....do.....	Polynesians.
80	.....	31.2	.....do.....	From Indian mounds in the United States (Wyman).
20	6	30	Private collection of Dr. D. S. Lamb	Dissecting-room specimens, mostly negro and mulatto.
62	17	27.4	U. S. Army Medical Museum	From Indian mounds in the United States.
122	.....	25.6	Topinard, Éléments d'Anthropologie Générale, p. 1016.	Guanches of Canary Islands.
156	.....	21.8	.....do.....	Dolmens and grottoes around Paris (Polished Stone period).
97	.....	21.7	.....do.....	African negroes.
61	12	19.6	U. S. Army Medical Museum	Ancient Cibolans (Hemenway collection).
28	.....	14.1	Topinard, Éléments d'Anthropologie Générale, p. 1016.	Melanesians.
30	.....	12.1	.....do.....	Dolmens of Imberon.
66	.....	10.6	.....do.....	Caverne de l'Homme-mort, Lozère (Polished Stone period).
388	.....	10.6	.....do.....	Dolmens of La Lozère (Polished Stone period).
288	22	7.9	U. S. Army Medical Museum	Pathological specimens, mostly from white soldiers.
27	2	7.4	Bulletins de la Société d'Anthropologie. Paris, Vol. v, p. 640.	From Chamont (Stone age).
16	1	6.2	U. S. Army Medical Museum	American negroes and mulattoes.
200	.....	5.5	Topinard, Éléments d'Anthropologie Générale, p. 1016.	Parisians from fourth to twelfth centuries.
96	5	5.2	U. S. Army Medical Museum	Modern American Indians.
150	.....	4.6	Topinard, Éléments d'Anthropologie Générale, p. 1016.	Parisians. Cemetery of the Innocents (Hamyand Sauvage).
218	.....	4.1	.....do.....	Parisians of the Middle Ages (Broca and Batuillard).
52	2	3.9	Revue d'Anthropologie. Vol. IX, p. 147	Europeans of America (Wyman, Peabody Museum reports).
30	0	0	Topinard, Éléments d'Anthropologie Générale, p. 1016.	Long barrows of England (Bronze age).

Perhaps some of the perforations were not counted. The bones of the Salado series, as before remarked, were very fragile, and the thin partition between the fossæ of the humerus was sometimes broken by accident. Pains were taken to distinguish between the natural and the accidental

* *Op. cit.*, p. 582.

perforations. There was usually no great difficulty in doing this, as the margins of the former were smooth and bounded a fenestration, regular or subregular in shape—often oval, while the irregular and fractured character of the margins of the latter was readily discernible. But it is probable that bones once perforated naturally were afterwards perforated post-mortem by fractures which included the natural fenestrations, or that the smooth edges of natural openings may have been abraded so as to give them the appearance of accidental openings; such cases would be excluded from the list.

FIG. 46.—Lower end of humerus showing large olecranon perforation.

Not only is the perforation more common in this than in any other race, but, as far as our observations among the various series in the Army Medical Museum teach us, the number of large perforations is proportionally greater. Such, at least, was the impression gained during the examination; but we did not determine this by actual measurement. Fig. 46 represents, natural size, the lower extremity of a left humerus of an ancient Saladoan in the Hemenway collection. It exhibits an olecranon perforation 11 milimeters in length by 7 in width.

The following table of five series in the Army Medical Museum shows that the perforation is more commonly found on the left side than on the right; yet even in this particular the Saladoans differ much from the rest of the races. While with them, as with others, the perforation is more commonly found on the right side, the difference between the two sides is not so great. This is shown in the last column of the table.

The subject of the olecranon perforation has been so extensively discussed* that we deem it well to do little more than give the results of our studies of the Hemenway series and other series in the Army Medical Museum, and indicate how our discoveries bear on the whole subject.

TABLE T.—*Showing percentages of olecranon perforation, on the right and on the left side, in different peoples.*

Race or collection.	Right.			Left.			Proportion of right to 100 left. Approximate.
	Number of humeri.	Number of foramina.	Per cent.	Number of humeri.	Number of foramina.	Per cent.	
Ancient Saladoans, Hemenway collection	43	19	44.1	46	29	63	70
Indian mounds, United States	35	7	20	27	10	37	54
Ancient Cibolans, Hemenway collection	30	2	6.7	31	10	32.2	20
Dr. Lamb's collection, mostly negro and mulatto	11	2	18.1	9	4	44.4	40
Pathological collection, mostly white soldiers	160	6	3.7	138	16	11.5	32
Total	279	36	12.9	242	69	24.3	53

We will attempt neither to cite the various theories which have been proposed to explain the nature and origin of the perforation, nor to quote the many arguments advanced to sustain these theories. We will merely announce that we are among those who believe that the perforation is not congenital but acquired; and that it has no connection with the rank a people may hold in the scale of races, but is the result of some mechanical cause connected with their occupations. We believe, furthermore, that it results from repeated and forcible extension of the forearm, in which the summit of the olecranon process of the ulna impinges against that thin bony partition which

* For a synopsis of the discussion and a bibliography of 49 titles, see "The Olecranon Perforation," by Dr. D. S. Lamb, in The American Anthropologist for April, 1890.

ordinarily separates the coronoid from the olecranon fossa of the humerus. The absorption of this partition and the consequent formation of a perforation connecting the two fossæ naturally follows.

Fig. 47 represents the anterior aspects of the distal extremities of both humeri from the skeleton of a young subject in the Salado series. The right humerus has a single large olecranon opening. In the left humerus the partition between the two fossæ is of a translucent thinness and is perforated by a number of small orifices which outline a space larger than the perforation in the right humerus. This left humerus is believed to present an olecranon perforation in the first stages of its formation. No other specimen of this character has been seen by us.

FIG. 47.—Lower ends of humeri showing olecranon perforations.

Our whole museum collection shows the perforation in two adolescents but in no infants. As far as we can learn the same fact has been observed with regard to children in other collections, and this is one of the facts on which rests the theory that the perforation is acquired and not inherited.

If it be granted that the perforation arises from mechanical causes and is the result of labor which requires repeated and forcible extension of the forearm, we need not search long to discover the existence of such labor among the aborigines of the southwest, both ancient and modern. The females of the modern pueblos are engaged during the greater part of their time in grinding corn, and they begin to perform this labor while they are yet very young. The grinding is done on a metate or large flat stone, by means of a smaller stone which is held in the hands of the operator and moved back and forth. The chief extension is made in moving the stone forward, and this requires the most forcible extension of the forearm. The motion is made chiefly by the muscles of the back. The discovery of numerous *metates* and upper grinding stones in the ruins of the Salado cities shows that the people practiced a method of grinding similar to that of the modern sedentary Indians of the same region. There were, no doubt, other labors which required great extension of the forearm, but this we believe was the most important.

Modern agricultural tribes of the North and East ground their corn in wooden mortars with wooden pestles; and in so doing made motions very different to those employed in operating with the metate.

Pruner Bey expresses the opinion that this peculiarity is, in the human race, to be found only in females, because all the humeri in which he noted the perforation were small. We can not say, for certain, that it is found only in female humeri, in the Salado series, because we can so rarely determine the sex of these skeletons; but it is not improbable that the perforation may be shown to occur more frequently among the females than among the males. Although the men did much hard labor of various kinds the work of grinding the corn was, in all probability, with the ancient Saladoans, as with the modern pueblo Indians, performed exclusively by the women.

That the perforation is not a peculiarity of females in all races is evidenced by the pathological series of the Army Medical Museum. In this series is a percentage of 7.9 perforations in 288 humeri, and these bones are, with few exceptions, derived from American soldiers of the Caucasian race. It is easy to conceive that many of our modern mechanical employments, such as that of the carpenter propelling the plane, in which the arm is forcibly extended, might cause the perforation we speak of. We have in our anatomical series the skeleton of a Frenchman showing the perforation on one side.

On the supposition that the perforation is produced by mechanical causes, we can account for its preponderance on the left side only by supposing that the left arm, in many occupations, is

more frequently and forcibly extended than the right. For the majority of human manual tasks we are not prepared to demonstrate this, although we might do so in some instances. In the work of grinding on the metate, however, it appears that the left hand is used the more. When the grist is lifted from the trough and placed on the metate—and this is very frequently done—the right hand is employed while the left hand is not released from the grinding-stone.

§ 32. THE PELVIS.

Pelvic measurements have been practiced upon 19 articulated pelves besides one pair of innominate bones, 2 innominate bones of separate individuals with their corresponding sacra, 1 without sacrum, and 8 separate sacra (Tables LXI to LXVIII, inclusive).

The measurements are as accurate as could be hoped for in pelvimetry where landmarks are relatively quite indistinct.

No measurement has been permitted to originate with us. The series of 19 measurements are compiled from Garson* and Verneau.† Fritsch,‡ Davis,§ and Bacarisse,‖ have also been consulted and the choice of each measurement determined by its frequency in use and its clear definition fully as much as by its apparent morphological utility. It was our orginal intention to extend the number of measurements to 21 by including a measurement of the height of the entire articulated pelvis and the subpubic angle; but although both these measurements have often been taken by investigators, we could not find sufficiently exact definitions to warrant our adoption of them.

The indices which have been calculated by different authors are very varied. In view of this fact, and also because all published series of measurements which we have examined deal with series which compared to craniological series are absurdly small, we have limited our indices to the two which Topinard especially recommends,¶ and a few others which appear most useful in the discrimination of sex.

Verneau, however, seems to base his discussion of sex on anatomical differences and absolute measurements, while J. G. Garson and most other writers have given us practically no information concerning the male pelvis. Hence as we are dealing with an unknown people, indeed almost all American tribes are unknown to pelvimetricians, and a people of probably conspicuously small stature, we might very readily go astray in applying to any great extent the canons or results of European anthropometry.

With these considerations in view we have decided upon the following indices:

First.—The breadth-height index or relation of the maximum external width of the pelvis at the iliac crest to its maximum height, or, which is the same thing, the maximum length of the innominate bone.

$$\text{Formula: } \frac{\text{Pelvic width} \times 100}{\text{Pelvic height.}}$$

Second.—Index of the superior strait.

$$\text{Formula: } \frac{\text{Antero-posterior diameter of brim} \times 100}{\text{Transverse diameter of brim.}}$$

Third.—Index of the pubo-ischiatic depth.

$$\text{Formula: } \frac{\text{Pubo-ischiatic depth} \times 100}{\text{Maximum width of superior strait.}}$$

Fourth.—Index of sacral length.

$$\text{Formula: } \frac{\text{Sacral length} \times 100}{\text{Maximum width of superior strait.}}$$

* Garson: Pelvimetry; Journal of Anatomy and Physiology, London, 1881-'82; pp. 106 *et seq.*

† Verneau: Le Bassin; Paris, 1875.

‡ Fritsch: Die Eingeborenen Süd-Afrika's, Breslau, 1872, Tabelle II.

§ Davis: Thesaurus Craniorum, London, 1867, Appendix B.

‖ Bacarisse: Du Sacrum, Paris, 1873; Thèse pour le doctorat.

¶ Topinard: Éléments d' Anthropologie Générale, Paris, 1885, p. 1049.

Upon inspecting the pelves we find them forming two groups. In the one group are Nos. H. 6, H. 7, H. 14, H. 18, H. 19, H. 25, H. 41, and H. 72. These present all the ordinary characteristics of the male pelvis. In the other group we find Nos. H. 1, H. 5, H. 8, H. 10, H. 15, H. 36, H. 39, H. 45, H. 57, and H. 59. These represent females.

No. H. 96 is the pelvis of a very young person. The ilia, ischia, and pubes are not coössified. Hence, we do not attempt to determine its sex, and omit it from our calculations.

The data furnished by the breadth height index and the index of the superior strait accord to the Saladoans a high place in the human series. With regard to the breadth-height index, both the males and the females stand at the top of the scale. With regard to the index of the superior strait, the females stand at the highest (arithmetically the lowest) end of the scale above the Europeans. The males occupy a medium position.

The other indices are of use in comparing the sexes, but we have never seen any comparative data concerning them in print.

We have prepared four ordinations, one for each index. These, especially the indices of pubo-ischiatic depth and that of sacral length, show very prettily the natural grouping of the sexes. (See Tables LXII to LXV, inclusive.)

NOTE.—In the table of measurements of the pelvis the abbreviation "5 v" is occasionally found after figures concerning the sacrum. This is used in cases where the sacrum consists of six vertebræ, to indicate that only five of them are measured.

LIST OF MEASUREMENTS.

1. Conjugata externa.—Antero-posterior maximum diameter of the pelvis: From the antero-superior part of the symphysis pubis to the summit of the spinous process of the first sacral vertebra.

2. Crest width.—Width between the crests of the ilia: Indicated by the greatest width between the external surfaces of the crests.

3. Antero-superior spinal width.—Width between the anterior-superior spines of the ilia: From the center of the most prominent part of one spine to the corresponding point on the other.

4. Postero-superior spinal width.—Width between the posterior-superior spines of the ilia: Measuring from the center of the most prominent part of one posterior-superior spine to a similar point on the other.

5. Antero-posterior diameter of the brim.—From the anterior-superior margin of the promontory of the sacrum to the most adjacent point of the symphysis pubis.

6. Transverse diameter of the brim.—Maximum width measured at right angles to the antero-posterior diameter.

7. Antero-posterior diameter of outlet.—Width between the center of the anterior-inferior margin of the body of the fifth sacral vertebra and the most adjacent point of the symphysis pubis.

8. Transverse diameter of outlet.—The maximum width of the pelvic outlet measured at right angles to the antero-posterior diameters of the outlet, between the most widely separated points, on lines passing parallel to the brim line from the spines of the ischia to the lower ends of the obturator foramina.

9. Sciatic width.—Minimum distance between the sciatic spines.

10. Pelvic height.—Maximum length of the innominate bone or pelvic height.

11. Iliac breadth.—Maximum breadth of the ilium.

12. Height of iliac fossa.—Height of the internal iliac fossa from the superior strait to the most elevated point of the iliac crest. (Upon the superior strait Verneau's *point de repère* is situated at the middle of the distance which separates the sacro-iliac articulation from the point which corresponds to the maximum transverse diameter of the strait.)

13. Cord of the brim.—From the sacro-iliac articulation to the symphysis pubis (at the level of the superior strait).

14. Pubo-ischiatic depth.—The distance between the upper surface of the pubis and the lower surface of the ischium, from the smooth level surface on the pubic side of the ilio pectineal suture above to the lowest part of the tuber ischii.

15. Acetabulo-symphysial width.—Width between the posterior margin of the acetabulum and the symphysis pubis.

16. Sacral length.—Vertical length of the 5 sacral vertebræ.

17. Sacral breadth.—Maximum breadth of first sacral vertebra.

18. Width of sacrum at brim.—Width of the superior strait at the reunion of the anterior face and the base.

19. Inferior width of sacrum.—Width of the sacrum below (at the inferior part of the auricular surface).

§ 33. THE COLUMNAR OR PILASTER FEMUR, *FÊMUR À COLONNE.*

We have studied this peculiar form of the femur, not by classifying the bones according to 6 different degrees as first recommended by Broca, but by finding an index as he later advises. (See Tables LXIX to LXXIII.) In order to obtain this index we took two transverse measurements of the diaphysis at its center—one antero-posterior, the other lateral; we multiplied the former by 100 and divided the product by the latter as directed by Topinard.* Our results, therefore, may be compared with a table given by Topinard. Our maximum index is 147.61. Our average indices are for 66 right femurs, 114.74, for 65 left femurs, 116.94, and for 131 femurs of both sides, 115.83 (Table LXXII). In 15 series which Topinard gives us, representing ancient and modern Europeans, Negroes, New Caledonians, and anthropoids, but three are higher than the Saladoan. These are: 1 nameless femur, 158; 1 femur from Cro-Magnon, 128, and 5 femurs from the Grand Canaries, 117.5. These series are all so small that they can not be compared with ours to good advantage. Indeed, Topinard has no series approaching ours numerically; his highest is 20 African negroes. We are not, then, able to judge with any degree of exactness where the Saladoans stand among the various human races and the lower orders of animals in respect to lateral compression of the shaft of the femur, and prominence of the *linea aspera;* but we may safely say that few, if any, races of men possess these peculiarities to a more exaggerated degree, and that few if any are further removed in these particulars from the anthropoids. Whatever, then, are the causes which produce the pilaster femur, they may be sought among the Saladoans.

It has been often observed among other races that the pilaster femur and the flattened tibia are associated features, and the Saladoans offer no exception to this rule. The flattening of the tibia is perhaps more remarkable among them than the lateral compression of the femur. We have some evidence, too, that, in this series at least, these features are associated in a direct though not symmetrical or constant ratio. This is shown in Table LXXIII, in preparing which we have selected 5 skeletons whose tibiæ showed the lowest indices, *i. e.*, the greatest lateral compression, and 5 other adult skeletons whose (normal) tibiæ exhibited the highest indices and the least lateral compression. For these 10 skeletons we have presented side by side the tibial and femoral indices, and computed averages for the two groups separately. It will be seen by consulting the table that the low tibial indices are accompanied by high femoral indices, and vice versa; in other words, the lateral compression of the femur is in a general way proportionate to the lateral compression of the corresponding tibia. Since the lateral diameter is employed as the dividend in computing the index of the tibia, and the antero-posterior diameter is so employed in the index of the femur, the indices of these bones bear an inverse relation to one another, *i. e.*, the narrower laterally the tibia, the lower the index; the narrower the femur, the higher the index. These observations lead us to the conclusion that whatever causes operate to produce the platycnemic tibia operate as well to produce the pilaster femur. Under the next section (§ 34) we consider these causes with regard to the tibia, because in that connection we fancy we can discover their operation more plainly.

§ 34. PLATYCNEMIA, OR FLATTENED TIBIA.

There is probably no single series of bones in any collection which offers better advantages for the study of platycnemia than the bones of the Salado. They belong to a race apparently very homogeneous, whose general habits of life are well understood, and they present this peculiar

* *Op. cit.*, p. 1019.

formation more constantly and in a higher degree than those of any other collection of which we have seen a record. Furthermore, the series is extensive.

In obtaining the index of the tibia for this study we have adopted the method of Broca; that is, we have measured the bone at the level of the nutrient foramen, have multiplied the transverse dimension by 100 and divided the product by the antero-posterior dimension. We have found in the Salado collection 116 tibiæ sufficiently preserved to admit of these measurements. Ninety of these, which were collected along with the skulls or other bones of the same skeletons, and which were conserved immediately on being disinterred, are given in Table LXXIV. Twenty-six of the tibiæ form a miscellaneous group; they were gathered singly and belong mostly to skeletons which in the earlier days of the work of excavation were allowed to disintegrate from exposure to the weather or were crushed under the feet of thoughtless visitors. Since many of this miscellaneous set are cracked and warped, we repose less confidence in their dimensions than we do in the dimensions of the series of 90; hence we devote to them a separate table (LXXV).

It is a recognized fact that the flattened tibia does not occur in childhood, but that the peculiarity is acquired as years advance. To include immature tibiæ in the general average may therefore be thought to improperly diminish the average of platycnemia and increase the average index. We have two skeletons in which there is an exostotic crest, apparently the result of unusual muscular traction, posteriorly near the junction of the perpendicular with the oblique line. This formation, on the other hand, by falsely increasing the antero-posterior diameter, may be thought to improperly increase the average of platycnemia and decrease the average index. In Table LXXIV we have noted under the head of "Remarks" all instances of these disturbing factors, and we have calculated averages both inclusive and exclusive of such instances.

If we take an index of 75 as representing a normal tibia (and this may be regarded as a low standard) we find but four adult tibæ in 116 which may be regarded as normal. The lowest American index we have seen recorded is one of 48 in a tibia from a mound in Michigan. This instance is mentioned by Jeffries Wyman,* who expresses the index by saying that the transverse diameter is 0.48 of the antero-posterior diameter. In this connection he never uses more than two decimal figures; consequently the index, if expressed in the manner adopted by us, might have been a fraction higher. We may safely say then that two tibiæ of the Salado series (those of H. 19) are as low as the lowest American known. Absolutely the lowest for all races we have seen recorded are 3 mentioned by Kuhff, one from *Caverne de l'Homme Mort*, having index 47, and two from the Grand Canaries, having indices 42 and 36.

The most extensive table of averages we have observed is one of 39 series given by Dr. Kuhff.† In this the lowest averages are in series having but 1 or 2 specimens in each, and they therefore do not admit of comparison with ours. The lowest average he gives in any series comprising more than 2 specimens is that of certain prehistoric bones ("Lehm de Kollwiller") from Alsace, of which there are 11 specimens. The average index is stated at 63; but Dr. Kuhff gives no decimals in his table. The average of all our 116 tibiæ is 63.54 (Table LXXV); the average of 90 of the more perfect part of the collection, as shown in Table LXXIV, is 62.71; while the average of 78 adults free from complicating exostoses is only 61.88. We may safely say that no series of equal size in any collection will be found to show a higher average grade of flattening of the tibia than our Salado series.

The most satisfactory explanation which we have noted of the origin of platycnemia is that of Manouvrier.‡ We regret that we have never seen his original paper on this subject; we derive a knowledge of his work entirely from a review.§ He has concluded from a careful study of the tibia in its anatomical relations that the flattening is entirely due to "lengthening and straightening of the postero-external surface of this bone; that is to say, of the surface of insertion of the posterior tibial muscle," and this lengthening and flattening, Mr. Manouvrier wisely main

* Fourth annual report of the trustees of the Peabody Museum of American Archæology and Ethnology, Boston, 1871, pp. 21, 22.

† De la platycnémie dans les races humaines. Revue d'anthropologie, second series, vol. IV, p. 255.

‡ Platycnemia in men and anthropoids. Memoirs of the Anthropological Society of Paris, 2d series, Vol. III.

§ Revue d'anthropologie, third series, vol. IV, 1889, pp. 207–210.

tains, is due, not to the direct but to the inverse action of the muscle, produced under the influence of repeated, almost constant work. He shows that the flattening is not similar to that observed in the anthropoids; that it results from the action of a different set of muscles; that it is not one of the "simian characteristics" which we are so prone to find in races whom we consider inferior to ourselves; that it is an evidence not of inferiority, but of superiority, since it is produced under the influence of a cause essentially human.

This inverse action of the *tibialis posticus* is exerted when the foot is fixed and the tibia raised, as in the act of rising from a kneeling position. "This traction," says the reviewer, probably following Manouvrier, "is produced in the upright position; more still in walking, above all up inclined planes, both in mounting and descending them, and infinitely more in running and jumping. It is, therefore, very probable that platycnemia should be found in great walkers, amongst the peoples of a varied country, living a savage life, hunting, etc. Children not presenting it shows it to be an acquired characteristic which is developed only at a certain age, under the influence of special conditions. We can explain thus why it is less marked in the women, and why it presents in a given race very different individual degrees."

All the above suggestions as to causal activity are pertinent; but it seems to us that one of great importance remains to be made. When the *tibialis posticus* assumes the inverse action, the tibia becomes a lever of the second class, with the fulcrum at the ankle joint, the power at the insertion of the muscle, and the weight (which in ordinary cases is but the weight of the body and the clothing) at the knee-joint. There are three ways (besides frequency of impulse) in which the muscle that supplies the power may be called into increased action: First, by increasing the distance through which the lever moves, as in climbing hills; second, by diminishing the time in which it moves, as in running and jumping; third, by increasing the weight, as in lifting and carrying heavy loads. Largely to the third way we are inclined to attribute the prevalence of platycnemia among various American races, including the Saladoans. The latter lived in a wide plain some distance (10 miles at Los Muertos) from the nearest mountains, which are neither remarkably high nor steep, and it is probable that, except for religious pilgrimages, they resorted rarely to these barren summits—as unproductive, no doubt, in ancient days as they are now. The Saladoans were, then, not mountain-climbers. As they did not subsist to any great extent on game, their exercise in running was probably mostly confined to their sports. But they had no large domestic animals and were obliged to be their own burden-bearers. The burdens, too, were not dragged after them in vehicles, but were carried on the head or the back. Thus was the harvest brought home; thus were the materials collected and elevated to construct their tall houses, and the earth that was taken from their vast canals and reservoirs was carried out in baskets on the backs of men and women. The work done in this way by the Saladoans must have been enormous.

We have now in mind many facts connected with the customs of other peoples which tend to strengthen this theory, but we will not take the present occasion to mention them. To those who are considering the problem of platycnemia in Europe we would suggest that they inquire what effect the introduction of large beasts of burden may have had on the form of the human tibia, and what effect such occupations as those of the porter and the hod-carrier may have in preserving the flattened form to a limited extent to the present generation.

We have not seen elsewhere noted a feature that is apparent on a slight inspection of the bones of this series, namely, that there is a flattening of the fibula which corresponds with that of the tibia. This correspondence is general but not uniform, *i. e.*, while no constant ratio can be shown to exist between the indices of associated leg bones, a very flat tibia is generally accompanied by a very flat fibula, an average tibia by an average fibula, and a normal tibia by a normal fibula. The index of the fibula is usually less than that of its companion tibia. To elucidate these points we give a short table, in preparing which we have selected for illustration, from the Salado series, two very flat, two average, and two normal tibiæ. We have added one European tibia. All are from the right side.

TABLE I'.—*Flattening of tibia and corresponding fibula.*

Designation of skeleton.	Antero-posterior dimension of fibula.	Transverse dimension of fibula.	Index of fibula.	Index of associated tibia.
H. 19	19½	9½	40.87	48.75
H. 6	16½	10½	63.63	49.29
H. 15	13	7	53.84	62.26
H. 14	17	10	58.82	62.50
H. 36	14	9	64.28	75.43
H. 74	15	10½	70.00	79.03
Caucasian	15	10½	70.00	75.75

The measurements of the fibula were taken at the point where the maximum antero-posterior diameter was found. It is possible that, had some other point been selected for measurement, a ratio more nearly constant between the indices of the two bones might have been discovered.

The flattening of the fibula is accompanied by the following changes in the form of the bone: The entire shaft is twisted outward on its axis; the anterior portion of the internal surface is brought more to the front, almost forming a true anterior surface to the bone; the interosseous ridge, becoming more permanent and advancing to the front, divides the internal surface more sharply into two surfaces; the internal border becomes less distinct and allows the posterior surface, which largely loses its identity, to become merged with the posterior part of the internal surface. The bone is thus apparently compressed between the insertion of the *tibialis posticus* on the inside and the insertions of the *peroneus longus* and *peroneus brevis* on the outside. The two latter muscles are in their action adjuncts of the first. The "channeling" of the fibula noted by other observers is also found associated with these changes.

The columnar femur and platycnemia in various races.—Measurements have been taken to determine the relation of the various races as far as they are represented in our collections at the Army Medical Museum. This investigation has been fairly exhaustive and has embraced the large majority of all our accessible skeletons in good condition. In all 62 skeletons have been measured.

But even with all this number of individuals we find but two, or at most three, series which are sufficiently large to serve as the foundations of generalized assertions. These series are:

First, twenty-four Sioux Indians; second, twenty three other Indians; third, six Negroes. (See Table LXXVIII.)

The reason why the Sioux are separated from the other Indians is simply because they form a sufficiently large series and not on account of any presupposed differences as to platycnemia and the pilaster femur. It might be as well in the present state of our knowledge to reckon all the Indians together and hence we have said above that the number of our comparative series of indices may be considered as either two or three.

The facts to be noted are that the Saladoans stand between our negroes and Indians with regard to the pilaster femur, while they possess tibiæ of a higher degree of platycnemia than any of the other races.

From the lists of the individual measurements and indices some curious data may be culled. We note the following as regards the columnar femur. (See Table LXXVI.)

Both the maximum and the minimum of the series are represented by bones of hunchbacks. The minimum index, that of the left femur of a white male, No. 5433, amounts to only 92.15. The maximum, which to the best of our knowledge is the highest index of the kind on record, is that of the right femur of the female negro, No. 5432, and amounts to 159.18. This surpasses by 1.18 per cent the femur of unknown origin which Topinard mentions as having the highest index of which he has ever been made aware.* There is nothing about this remarkable bone to suggest the action of disease. It is true that most of the arching forward, which we observe in all femora, is localized in this bone at about the junction of the upper and middle thirds. But this is a com-

*TOPINARD, *op. cit.*, 1019.

mon form. Indeed, judging from a plaster cast in the Army Medical Museum, we believe it to be the form of the celebrated femur of Cro-Magnon, whereof the index is 128. There is no suggestion of disease about the coxæ nor about the leg bones of this negress's skeleton, nor is there any peculiarity of the skeleton as a whole which in any conceivable mechanical means could have brought about such a result.

Two other hunchbacks, the one mentioned as having the minimum index of the section of the femur, and also No. 938, an Alaskan, show no such peculiarity.

In connection with platycnemia let us mention the Bannock male, No. 2133 (Table LXXVII). The indices of his tibiæ are 85.07 for the right and 93.75 for the left. These figures, while not the highest on record, are nevertheless very high, and show an entire lack of platycnemia, if we may so express it. This is not what we should expect to find in an Indian skeleton, according to the facts learned in pursuing our investigation.

It happened thrice in our series of tibiæ that the nutrient foramen of a certain tibia was so very far out of normal place that it would falsify any measurement. Upon finding such a bone we would compare it to its fellow of the opposite leg of the same individual and measure it at a position corresponding to the level of the foramen in the latter. This is indicated on the margin of our tables.

HUMAN BONES

OF

THE HEMENWAY COLLECTION.

PART II.

THE SERIES OF CIBOLA.

PART II.—THE SERIES OF CIBOLA.

§ 35. THE SERIES OF CIBOLA.—ORIGIN, CONDITION, ETC.

The skeletons disinterred in the neighborhood of Zuñi are said to number about 200. Thirty-five of these, complete and incomplete, have been received at the Army Medical Museum. The others are stored in a house at Zuñi. These 35 were not selected for any scientific reason, but were packed and shipped because nearest at hand when the expedition was about to break up at Zuñi. They are mostly hard and in good condition, and present a striking contrast in this respect to the bones from the Salado Valley. They came mostly from the ruins of Heshota-uthla, which is about 13 miles in an easterly direction from Zuñi and further up the valley of the Zuñi River.

Heshota uthla was not one of the seven cities of Cibola. There is no doubt among those who have thoroughly investigated the matter that it was a shapeless ruin in 1540, when Coronado's army passed near its site. According to Zuñi tradition it was occupied in a remote antiquity by a people of their own race. Of this there is no evidence save tradition; yet for the present we place the remains of Heshota uthla along with the other remains from the same neighborhood in the series of Cibola. Archæological investigation shows that the people of Heshota-uthla had the same customs, arts, and general civilization as those of Cibola.

The ruin of Heshota-uthla, which was when inhabited a large, compact, many-storied pueblo, capable of sheltering a thousand or more people, lies close to the main wagon road from Zuñi to Wingate. Before excavations were begun it seemed to the untrained eye a natural heap of talus; the careful investigation of the scientific observer only revealed the fact that it was the ruin of a great edifice reared by human hands. Between the years 1880 and 1884 the writer frequently inspected this ruin alone and in company with Mr. Cushing and others, and it was then the general opinion that the heap of stones in sight represented the entire walls of the building from top to base. The recent excavations have shown that the loose stones were the débris of the upper stories only, the third and fourth perhaps, and that the first and second stories were buried from sight. The floors of the buildings were found at depths of 10 and 12 feet under the general surface of the ground—to such a depth had the surrounding soil accumulated by the washing of earth down from the neighboring hills and other natural causes since this pueblo was inhabited.

The skeletons in Heshota-uthla and in Hawicu, as in the ruins of the Salado Valley, were found buried under the floors of the houses, but not with such care as in the latter place; no mud-walled graves were found, only ordinary holes in the earth, and the bodies were laid in all directions with relation to the points of the compass.

We have not given the same attention to the Cibolan collection as we have to the Saladoan. We have had less time to devote to it, and besides we have not thought it proper to give the Cibolan remains the fullest consideration until we should come into possession of the whole collection, which we hope to do at no distant day. We have taken some of the more important measurements and made sufficient study to enable us to draw a comparison between the skeletons of the Salado and those of the Zuñi Valley.

Some of the 35 skeletons come from Hawicu, the Ahacus of Coronado. This was about on the site of the present inhabited pueblo of Zuñi. The bones were exhumed near the main pueblo on the opposite bank of that narrow and inconstant streamlet known as the Zuñi River, and in the immediate vicinity of houses now occupied by certain extramural or outcast Zuñians.

§ 36. CEPHALIC INDEX. CIBOLA.

The antero-posterior shortening, which is such a marked feature of the Saladoan skulls (§ 6), is no less a marked feature of the skulls of Cibola. The tables (LXXXIII, LXXXIV) indicate even a greater shortening in the latter series. The shortest skull is broader than it is long, having an index of 100.69, a greater exaggeration of this shortening than is found among the Saladoans,

whose highest index is 97.97. We have seen record of but few indices higher than the above of 100.69. The average cephalic index of this group (88.86) is higher than that of the Saladoans by a small fraction, notwithstanding that there are 5 Cibolan skulls longer than the longest Saladoan.

The minimum index, 74.54, which is dolichocephalic according to some authorities, belongs to a skull apparently normal and possibly of an alien race.

The supposed reasons for this shortening have already been declared.

§ 37. OCCIPITAL FLATTENING. CIBOLA.

This deformation, whatever be its significance, is the rule in the collection under consideration. Only 4 skulls, indeed, Nos. H. 201, H. 204, H. 221, and H. 229, can be called normal in outline.

Of the deformity of the remaining skulls it may be said that it can be most impressively explained by imagining it to have been made by a flat rigid surface moving in a plane vertical or tilted a little forward with reference to the antero-postero-horizontal plane of the skull, coming in contact with the occiput. Hence we find the flattening in the less notable cases involving only the most prominent part of the occiput, that is, from inion to lambda. Then we find a number flattened from inion to obelion, and lastly a few in which the whole occiput is affected. But this plane, while always approximately vertical to the aforesaid horizontal plane, may be either parallel to or at any angle with the transverso-vertical plane of the skull.

Hence the flattening may be strictly unilateral; or the flattening may affect both sides, but preponderate upon one; or the flattening may be bilaterally symmetrical. There are 10 skulls in which the flattening is nearly or quite bilaterally symmetrical. Eight skulls are flattened on the left side of the occiput, and twelve skulls are flattened on the right side of the occiput.

There is no skull exemplifying that occipital flattening wherein the occiput seems to have been in contact with a force pressing upward and forward. The resultant form is one in which the obelion is, or tends to be, the most posterior part of the skull, while the surface from the lambda to the inferior curved line, or even to the opisthion, forms a nearly continuous plane.

§ 38. VERTICO-LONGITUDINAL INDEX. CIBOLA.

The general remarks under the title "Vertical indices" (§ 11) made on the Saladoan skulls apply as well to the Cibolan, although we have placed on record for the latter only one vertical index, the vertico-longitudinal, whose factors are the greatest length and the basi-bregmatic height. (See Tables LXXXIII, LXXXIV.)

We found it possible to compute this index in 31 skulls only. The extremely short skull, H. 216, which gave such a high cephalic index, gave the still higher vertico-longitudinal index of 101.39, which was the maximum of the series; but it was not the normal skull with the lowest cephalic index (H. 209) that had the minimum vertico-longitudinal of 74.05. The variation of this index in the series of 31 is greater than in the Saladoan series of 39, and the average of the one series exceeds that of the other by 5 units.

The cephalic index and the vertico-longitudinal index of the Cibolan group are exactly the same in two cases* and they are within a unit of one another in 5 cases more.† The close correspondence of the maxima, the minima, and the averages in both indices may be seen by consulting Table LXXXIII.

§ 39. PLANE OF THE FORAMEN MAGNUM. CIBOLA.

In 27 skulls of this series we have been able to estimate the angle of Daubenton and the analogous basilar and occipital angles of Broca. (See Tables LXXXII, LXXXV.)

We found in the skulls of the Salado the highest expressions of these angles—higher than any previously on record, and we had thought that this might be a concomitant of the occipital distortion and due to pressure on the occiput in infancy, which caused the plane of the foramen magnum to incline more posteriorly. In the skulls of Cibola there is, to judge from the cephalic indices, as much of this flattening as among those of the Salado, yet the angles which indicate the inclination of the plane of the foramen magnum are not nearly so great in the former as in the

* Nos. H. 215 and H. 228. † Nos. H. 202, H. 213, H. 216, H. 217, H. 226.

latter. They are the same among the Cibolans as they are in races with long heads who have no practices that result in flattening. For instance, according to Topinard,* the average angle of Daubenton is among Esquimaux, Hottentots, and Australians 6°, and among Javanese, Polynesians, and New Caledonians 7°, while among the Cibolans it is intermediate between these two, or 6½°. But it must be stated that Topinard omits fractions.

§ 40. PROCESSES AT BASE OF SKULL. THE INION. CIBOLA.

In general, the processes at the base of the skull are somewhat more prominent in the Cibolan than in the Saladoan skulls. This is particularly noticeable in the case of the inion, or, more properly speaking, the superior curved line in the region of the inion.

We have estimated the degree of projection of the inion indirectly from orthogonal drawings of the occiput. These drawings represent the most prominent points, whether they be in the sagittal plane or not. Hence if any part of the superior curved line of the occiput be more prominent than the inion proper, it is that which is represented upon the drawing and compared with the standard. This greater prominence of the superior curved line at one side of the insertion of the ligamentum nuchæ is met with several times (well marked in 8 cases; see Table LXXXVI) in the skulls under discussion. In general, the inion does not project much downward as a free process from the occiput, but is part of a large elevated bone area, quite distinct, and corresponding to the median part of the superior curved line. In short, it is the insertion of the trapezius muscle rather than the insertion of the ligamentum nuchæ which is exaggerated.

This greater prominence of the inial region of the Cibolan over the Saladoan skulls may be due to the fact that the pressure which flattened the skulls seems to have been exerted in the former entirely on a surface above the inion, while in the latter it was usually on a surface which included the inion. This remark must be taken in connection with what we have said in § 9.

In the Saladoan skulls none of the inia are more prominent than Broca's No. 1. In the Cibolan skulls (see Tables LXXXVI and LXXXVII) 12 out of 32, or three-eighths of all, correspond with higher numbers of Broca's scale. There is one which we consider as equaling his No. 4.

§ 41. THE PTERION. CIBOLA.

We have found in this series 40 pteria which admitted of measurement. They are equally distributed between the right and left sides. Eighteen skulls have both pteria intact. They are all of the form "pterion in H," but two are complicated with epipteric bones. (See Table LXXXVIII.)

The longest right pterion is 18^{mm}; the longest left pterion, 24^{mm}. There are two pteria of the right side measuring 9^{mm}, but none measuring less. There are two of the left side measuring 7^{mm}, and this is the minimum of the whole group. The average length of the right is 14.60^{mm}, of the left 13.55^{mm}, of all 14.07^{mm}. These averages are higher than those of Salado.

In the Cibola, as in the Salado group, there are but two pteria less than 8^{mm} in length, but, as the Cibolan series is greater, it shows a smaller percentage, which is only 5.

Placing the above figure along with Anoutchine's tables, previously quoted, we find that the Peruvians have of all races the smallest percentage (3.4) of pteria—less than 8^{mm} in length; that the Cibolans come next, with 5 per cent; the Saladoans third, with 6.5 per cent; the "People of the Caucasus, Turkestan, and Turko-Finnish" fourth, with 6.9 per cent, and that all other races have higher percentages, the highest being the Australians and Tasmanians, 24.6 per cent.

Like the Saladoans, the Cibolans show no frontal apophyses at the pterion, and they show but two epipteric bones (5 per cent), less even than the Peruvians, whose per cent (6) is the lowest on Anoutchine's table of 10 series.

In making this comparison it should be remembered that both of the series described in this report are much smaller than any of Anoutchine's, his lowest Australians and Tasmanians being 102.

* TOPINARD: *Op. cit.*, p. 814.

Anoutchine gives in another table a list of 12 series of diverse races, in which there are pteria less than 3mm in percentages, ranging from 0.5 to 8.2 (Chinese). Since the Peruvians do not appear on this table, we presume their percentage is zero. Such is the case with the Cibolans, but, as before stated, we found one of these small pteria in a Saladoan skull.

§ 42. INCA BONE AND KINDRED FORMATIONS. CIBOLA.

As we have not secured illustrations to show for this series the anomalies involving the superior angles of the vertical portions of the occipital bone, we have prepared a list of these anomalies, 12 in all, with a detailed description of each case.

List.—H. 203: In the left limb of the lambdoid suture there are Wormian bones, one of which sends a process across the apex.

H. 206: A typical *os apicis* 32mm high by 51mm broad. It has Wormian bones at its lower angles.

H. 207: A very curious multiple apicial bone reaching to within 3mm of the obelion. It consists of nine principal and many smaller portions. The whole group is 43mm high and 51mm wide, and might by some be considered an *os Incæ*. The bone forming the apex is 21mm by 17mm.

H. 210: Fine tortuous Wormian bones in both limbs of the lambdoid suture. There is one of this set at the apex, a small irregular ossicle, which might be regarded as an *os sagittale*.

H. 212: A large compound bone at the apex, mostly to the right of the median line. The lower part of it, about 40mm by 32mm, is partly coössified to the rest of the occipital. The upper part, about 22mm by 9mm, forms a small apicial bone. A few Wormian bones of small size complicate the lambdoid.

H. 213: A row of medium-sized Wormian bones in each limb of the lambdoid suture; one of these bones is on each side of the apex; 12mm above the apex is an *os sagittale* 18mm by 9mm.

H. 218: An apical bone in two parts slightly coössified. The total size is 25mm high and 47mm wide.

H. 223: A row of medium-sized Wormian bones, all of remarkably simple outline, in each limb of the lambdoid suture. One of these bones situated at the apex measures 14mm by 16mm.

H. 227: A large typical Inca bone 46mm high and 73mm wide. Above it is a small bone 7mm by 10mm, which may be regarded as an *os sagittale*.

H. 231: A triangular *os apicis*, 27mm by 53mm.

H. 232: A row of long, very irregular Wormian bones occupies the lambdoid suture throughout from the left asterion almost to the right; one of these bones, situated in the median line, is about 8mm by 14mm, and may be considered an apicial bone.

H. 233: A row of Wormian bones occupies the upper half of the right limb of the lambdoid suture; one of these, 13mm by 14mm, touches the median line at the apex.

From the above list we learn that there are in this series the following anomalies: 1 typical Inca bone, H. 227; 5 typical apicial bones, Nos. H. 206, H. 207, H. 212, H. 218, H. 231; 6 doubtful apicial bones, Nos. H. 203, H. 210, H. 213, H. 223, H. 232, H. 233, or 11 apicial bones of both classes—12 anomalies in all. The above numbers give us, in a series of 35, the following percentages: Inca bone, 2.85 per cent; true apicial bones, 14.28 per cent; doubtful apicial bones, 17.14 per cent; both classes of apicial bones, 31.42 per cent; total of all anomalies 34.28 per cent. From these percentages, from those given in paragraph 18, and from percentages obtained from our own collection we have prepared the following table:

TABLE W.—*Frequency of Inca bone in various peoples.*

Races.	Complete *ossa Incæ*.	True apicial bones.	Doubtful apicial bones.	Apicial bones of both classes.	All anomalies.
Saladoans	5.68	.....	.....	18.1	26.04
Peruvians	5.46	10.5?	.....	10.5?	17.63
Cibolans	2.85	14.28	17.14	31.42	34.28
Americans not Peruvians	1.30	5.63?	.....	5.63?	9.75

While this series is too small to enable us to institute a perfectly satisfactory comparison between it and others, we have nevertheless obtained data sufficient to allow us to conclude that, with regard to this class of anomalies, the Cibolans are in close relation to the Saladoans and the Peruvians, and widely separated from other American races and from the rest of the world.

§ 43. NASAL CHARACTERS. NASAL INDEX. CIBOLA.

The average nasal index is nearly the same in both the Saladoan and the Cibolan series; that of the former being 51.66, and that of the latter 51.88 (Table LXXXIV). The remarks, therefore, which apply to the one apply as well to the other. In respect to the maximum and minimum of this index, also, the two series correspond closely. The maxima are: For the Saladoan 61.11; for the Cibolan 60.46. The minima are: For the former 44.23; for the latter 45.09.

The character of the lower border of the nasal aperture or *échancrure* of the Cibolans seems from such evidence as we possess to be inferior only to that of the Europeans and Saladoans. For the two highest classes A + A′ (see Table LXXXIX) their percentage is 38.23. The lowest class, E, simian gutter, has no representative. Over one third of the series belong to class B. The relation with regard to this characteristic, which the Cibolans sustain to other races, will be seen by comparing Table LXXXIX with the tables in § 24.

§ 44. TORSION OF THE HUMERUS. CIBOLA.

The average angle of torsion (154.27°) of all the humeri, 48 in number, of this series is higher than that of any race recorded by Broca except the Mexicans (155°) and the Europeans. As his Mexican series numbers only 2 it is scarcely worthy of being cited in comparison. Excluding the Mexicans, the Cibolans follow in respect to this feature next after the Saladoans and Europeans in the category of the human race, as far as we have seen the record. They are widely separated from other American races. (See Tables XC and XCI.)

Like the majority of mankind, and unlike the Saladoans, the Cibolans have the maximum angle of torsion on the left side. Not 1 but 5 angles on the left are higher than the highest angle on the right. The minimum is on the right side and there are 3 angles of the right lower than the lowest of the left.

The maximum angle of torsion of the Cibolans (178°) is higher than the maximum angle of Saladoans and, as far as Broca's tables inform us higher than the maximum of any people except the French. But the average of the highest 3 angles (173°) is not so great as the average of the highest 3 Saladoan angles (175°).

The average of all the left humeri, 23 in number, is 159.20°, while that of all the right humeri, 25 in number, is but 149.40°, a difference in favor of the left of nearly 10°. This is a higher difference than exists in any one of Broca's series, which represents more than two bones, except the Arabians and Kabyles + El Goleah, in which the difference is 10.27°.

The variation is greater on the left than on the right; on the one side it has a range of 35°, on the other a range of 20°.

§ 45. THE OLECRANON PERFORATION. CIBOLA.

The Cibolans present this anomaly in a much less degree than the ancient people of the Salt River Valley, the so-called Mound-Builders, the Guanches, and other peoples. The perforations appear in only 19.6 per cent of the humeri of the Cibolans, while the humeri of the Saladoans show 53.9 per cent.

The ancient people of the Zuñi Valley, no doubt, ground their corn in the same manner as did the ancient inhabitants of the Salt River Valley, and it may very pertinently be asked why the humeri of the former are not so often perforated as those of the latter. Retaining the hypothesis before mentioned that the method of grinding corn was an important factor in producing the olecranon perforation, we account for this difference by supposing that the Cibolans subsisted less on corn, and hence had less occasion to grind it than their more Western congeners. The land around Zuñi is not nearly so prolific as that of the Salt River Valley, the climate is colder, and agriculture is far less remunerative. The mountains adjacent to Zuñi, heavily timbered, abound in game, and it is probable that the ancient Cibolans lived more by the chase and less by agriculture than the ancient Saladoans.

TABLE I.—*General Measurements.*—Salado.*

1. Special number.

2. Museum number.
3. Age, in the 6 periods of Broca: 1st, 0 to 6 yrs; 2nd, 6 to 14 yrs; 3rd, 14 to 25 yrs; 4th, 25 to 40 yrs; 5th, 40 to 60 yrs; 6th, 60 yrs up.
4. Sex: M for male; F for female; ? for doubtful.
5. Capacity in cubic centimetres.
6. Horizontal length: from glabella parallel with horizontal plane to a perpendicular tangent to maximum occipital point. Frankfurt 1.
7. Greatest length: from the glabella to the maximum occipital point. Frankfurt 2. Topinard 1. p. 354.
8. Metopic length: from the metopion to the maximum occipital point. Frankfurt 3. Topinard A.
9. Greatest width: perpendicular to sagittal plane (not over mastoid process or at posterior temporal ridge). Frankfurt 4; Topinard 2.
10. Biasteric or maximum occipital width. Topinard B.
11. Bijugular or inferior occipital width. Topinard C.
12. Bimastoid width or width of the cranial bases: distance between the ends of the mastoid processes. Frankfurt 13 a.
13. Inferior subtemporal width: from one subtemporal point to the other. Topinard E.
14. Two frontal widths: 1st, smallest frontal, Frankfurt 5, Topinard 4; 2nd, maximum frontal or greatest of frontal bone; Emil Schmidt.†
15. Two auricular heights: 1st auricular height, Frankfurt 8. 2nd auxiliary auricular height, Frankfurt 9.
16. Horizontal circumference: above the superciliary ridge and over the most prominent part of the occiput. Frankfurt 14; Topinard 5.
17. Two Divisions of the horizontal circumference: 1st, anterior; 2nd, posterior. Separated by supra-auricular curve. Topinard G.
18. Sagittal circumference: from nasion to opisthion. Frankfurt 15.
19. Three divisions of the sagittal circumference: 1st, frontal; 2nd, parietal; 3d, occipital. Topinard E.
20. Two vertical circumferences: 1st, vertical circumference perpendicular to horizontal plane. Frankfurt 16. 2nd, supra-auricular curve.
21. Two dimensions of the foramen magnum: 1st, length in sagittal plane; 2nd, width perpendicular to sagittal plane.
22. Zygomatic width: greatest distance between the zygomatic arches. Frankfurt 18; Topinard 8.
23. Bimalar width: from external extremity of small fronto-malar suture to same point opposite. Topinard 9.
24. Facial width: from inferior extremity of maxillo-malar suture to corresponding opposite point. Frankfurt 17; Topinard 11.
25. Inter-orbital width: Distance from one dacryon to the other; Topinard H.
26. Two facial heights: 1st, total, nasion to lower border of inferior maxilla; 2nd, upper, nasion to alveolar point. Frankfurt 19, 20.
27. Two nasal dimensions: 1st, length, nasion to upper border of nasal spine; 2nd, maximum width. Frankfurt 21, 22; Topinard 17, 18.
28. Two orbital dimensions: 1st, dacryon to opposite margin in grand axis; 2nd, greatest height perpendicular to preceding. Topinard 19, 20.
29. Two palatal dimensions: 1st, length of bony palate; 2nd, median width of palate. Frankfurt 27, 28; Topinard O, L (less exact).
30. Two palatine widths: 1st, posterior. Frankfurt 29; Topinard M; 2nd, anterior, between canine and second incisor; Topinard K.
31. Depth of palatine arch: maximum, from alveolar edge, avoiding posterior palatine foramina. Topinard.
32. Two alveolar widths: 1st, external maximum, taken at level of malar region; 2nd, external posterior. Topinard.
33. Superior facial projection, or projection of the ophryon with regard to the alveolo-condylean plane. Topinard f.
34. Two widths of the lower jaw: 1st, external bicondy-ar; 2nd, external bigonial. Topinard 12.
35. Two dimensions of the ramus: 1st, height from angle to upper edge of condyle; 2nd, width, perpendicular to height. Topinard Q.
36. Basilo-mental radius: basion to mental point. Topinard S.
37. Superior alveolar radius: basion to alveolar point. Kollmann's "length of profile of face." Frankfurt 30; Topinard.
38. Nasal radius: basion to nasion. Topinard V, 7. "Length of cranial basis." Frankfurt 10.
39. Intersuperciliary radius: basion to glabella. Topinard W.
40. Metopic radius: basion to metopion. Topinard X.
41. Two vertical radii: 1st, "basilo-bregmatic diameter," Topinard 3; "auxiliary height," Frankfurt 7; 2nd, "Entire height" after Virchow.
42. Obelic radius: basion to obelion. Topinard Y.
43. Inial radius: basion to inion. Topinard Z.
44. Occipito-alveolar length: from maximum occipital point to alveolar point. Topinard 22.
45. Occipito-spinal length: from maximum occipital point to inferior border of nasal aperture. Topinard 23.
46. Two cranial projections: 1st, anterior or prebasilar; 2nd, posterior or post-basilar; both alveolo-condylean plane. Topinard d, e.
47. Profile angle (German): angle of naso-alveolar line on audito-orbital plane. Frankfurt.
48. Angle of Daubenton: sub-orbito opisthiac line with plane of foramen magnum.
49. Two other angles of plane of foramen magnum: 1st, occipital angle with naso-opisthiac line; 2nd, basilar angle with naso-basilar line.
50. Cephalic index: No. 9 ÷ 100 ÷ No. 7.
51. Vertico-longitudinal index: No. 41, 1st, × 100 ÷ No. 7.
52. Index of the foramen magnum: No. 21, 2nd, × 100 ÷ 21, 1st.
53. Facial index of Virchow: No. 26, 1st, × 100 ÷ No. 24.
54. Upper facial index of Virchow: No. 26, 2nd, × 100 ÷ No. 24.
55. Facial index of Kollmann: No. 26, 1st, × 100 ÷ No. 22.
56. Upper facial index of Kollmann: No. 26, 2nd, × 100 ÷ No. 22.
57. Nasal index: No. 27, 2nd, × 100 ÷ No. 27, 1st.
58. Orbital index: No. 28, 2nd, × 100 ÷ No. 28, 1st.
59. Palatine index: No. 29, 2nd, × 100 ÷ No. 29, 1st.
60. Gnathic index: No. 37 × 100 ÷ No. 38.

* All measurements in this table, not otherwise specified, are given in millimeters. † For further particulars as to measurements see § 2.

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1. Special number.

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31. Depth of palatine arch: maximum, from alveolar edge, avoiding posterior palatine foramina. Topinard.
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57. Nasal index: No. 27, 2nd, × 100 ÷ No. 27, 1st.
58. Orbital index: No. 28, 2nd, × 100 ÷ No. 28, 1st.
59. Palatine index: No. 29, 2nd, × 100 ÷ No. 29, 1st.
60. Gnathic index: No. 37 × 100 ÷ No. 38.

* All measurements in this table, not otherwise specified, are given in millimeters. † For further particulars as to measurements see § 2.

TABLE I.

TABLE I—Continued.

1	II, 1.	II, 2.	II, 3.	II, 4	II, 5.	II, 6.	II, 7.
2							
3	4th	4th	6th	3d	4th	5th	4th
4	F.	†	†	†	F.	M.	M.
5							1330cc
6	154	157	157	147	168	159	162
7	154	160	157	150	168	159	162
8	150		152	139	160	158	152
9		141	151	145	147	149	139
10		106		98		103	100
11	77	86	85	81	87c	86c	72
12	100	103	110	109		110	100
13	83	86			88		85
14	84	86; 119	97	82; 108	100; 123c	81; 119	93; 121
15	115; 115	125; 125	116; 116	114; 114	120; 120	120; 120	117; 117
16		483	491	459*	504	486	480
17		208; 275		205; 254	230; 274	246; 240	217; 263
18	330	319	339	329	354	342c	332
19		118; 126; 105		119; 112; 98	125; 113; 116		120; 111; 101
20		345; 319	322	325; 295	340; 320	343	334; 311
21		—; —	32; —; —	—; 29	56; 35c		35; 30
22	126	—	139		88		131
23	97	106	105	95	110	99	106
24	93	95	97	98	113	98	100
25		25	23½	18½		20	22
26	109; 68	—; 65	—; 71	110; 66	114c; 68	—; 68	—; 66
27	47½; 23	47; 24	51; 27	46; 25	50; 26	50; 23	50; 24
28	41; 34		39; 34	37; 36	41; 35	39; 33	40; 35½
29	56; 37	50; 36	50; —	49; 40	57; 38		52; 38
30	37; 25	37; —	—; 24	40; 26	39; 24		41; —
31	13	13		14	18		13
32	62; 49	62; 50	—; 52	67; 51	65; 49		63; 51
33	24	23	12	28	19c	15	19
34	114; 97		—; 97	—; 89	122; 95	—; 101	116; 99
35	56; 35	63; 32	55; 30	57; 29	60; 32	61; 32	56; 29
36	110			111	108		
37	100	99	92	98	99	105	97
38	99	97	101				
39	107	105	109	102	112	118	111
40	113	121	121	109	119	127	119
41	133; 134	141; 148	—; 138	128; 133	140c; 141c	—; 142	135; 136
42		141		122	135		123
43	54	76	65	57	68	65	64
44	186	199	180	201	203	176	193
45	171	187	168	184	189	170	183
46	105; 78	102; 88	94; 81	100; 86	101; 91	106; 72	99; 87
47	79½°	78°	86½°	77°	87°	86°	84°
48			15		11	10°	16°
49			24°; 31½		20°; 26°	19°; 24°	27½°; 36½°
50		90	96.17	96.00	87.50	93.71	85.80
51	86.36	90	88.59	85.33	83.33		83.33
52					97.22		85.71
53	111.65			112.24	110.67		
54	72.72	68.42	73.71	67.34	66.01	69.32	66.00
55	86.50						
56	53.96		51.43				50.38
57	48.42	51.06	52.94	54.34	52.00	46.00	48.00
58	82.92		87.17	97.29	85.36	84.61	88.75
59	65.48	73.00		81.63	66.66		73.07
60	101.01	102.06	92.07	110.11	96.11	95.45	97.00

* This is at the maximum occipital point; the circumference at lambda is 462.

TABLE I—Continued.

1	H, 8.	H, 9.	H, 10.	H, 11.	H, 12.	H, 13.	H, 14.
2							
3	5th	5th	4th	4th	5th	4th	4th
4	F.	?	F.	?	?	?	M.
5			1310cc			1170cc	1510cc
6	161	152	155	157	176	152	166
7	163	151	158	157	176	153	166
8	157	143	146	145	168	142	162
9	144c	132	143	138	139	134	147
10	104	105	103	111	109c	100c	99
11	76	85	87	83c	85c		82
12	109	112	115		108	107	110
13	80	85	82	83	86	84	86
14	91; —	89; 108c	88; 121	86; 111	94; —	84; 111	83; 118
15	119; 119	120; 120	123; 123	114; 114	116; 116	115; 115	122; 122
16	487	451	472*	463	494	455	488
17	213; 274	204; 247	204; 272	231; 230	229; 265	207; 248	229; 259
18	350	319	342	326c	370c	335	353
19	120; 128; 102	116; —; —	110; 133; 99	112; 108; 105	132; —; —	111; 112; 112	128; 123; 102
20	334	301; 283	336; 314	328; 294	332; 313	316; 292	350; 319
21	32; 30	34½; 33	35; 31			—; 29	36½; 30
22	131	126	126	129		127	128
23	105	103	104	101	109	101	101
24	90	101	93	100c	101	100	98
25	25		22	21	26	22	19½
26	—; 66	—; 69	—; 71	118; 71	—; 66c	—; 67	125; 78
27	47; 24	49; 22½	49; 23½	49; 24	—; 25½		53; 24
28	38½; 34½		42; 37	39; 37	40; 38	39½; 35½	37; 36½
29	51; 38	51; —	51; 36	51; 36	52; —		57; 41
30	38; —	36; 23	38; 22	39; 25			40; 25
31	12		18	14			18
32	52; 45	—; 49	62; 49	60; 52	—; 46	—; 51	62; 47
33		22	18	27	12	17c	25
34	115; 91		114; 95				116; 94
35	59; 33	56; 31	59; 27	61; 30½	63; 31	51; 30	63; 29
36				100			105
37	94	96	96	98		94	99
38				98		100	101
39	106	109	110	109		109	114
40	113	116	117	115		116	121
41	—; 140	135; 136	145; 147	133; 136		140; 143	138; 142
42		132				135	134
43	66	71	69	64		75	71
44	193	184	203	199	197	191	195
45	185	168c	186	185	193		184
46	95; 90	97; 82	96; 92	100; 91		99; 70	100; 98
47	84½°	78°	80°	80°		81°	86°
48	10½°		18½°				15½°
49	21½°; 28½°		30°; 38°				25°; 33½°
50	88.07	87.41	90.50	87.89	78.97	87.58	88.55
51		89.40	91.77	84.71		91.50	83.13
52	93.75	95.65	88.57				82.19
53				118.00			127.55
54	72.92	68.31	76.34	71.00	59.54c	67.00	79.59
55				91.47			97.65
56	50.38	54.76	56.34	55.03		52.75	60.93
57	51.06	45.91	47.95	48.97			45.28
58	89.61		88.09	94.87	95.00	89.87	98.64
59	74.50		70.58	70.58			71.92
60	95.91	91.83	96.00	100.00		94.00	98.01

*The maximum circumference is 476.

TABLE I—Continued.

1	H, 15.	H, 16.	H, 17.	H, 18.	H, 19.	H, 20.	H, 21.
2							
3	4th	4th	3d	5th†	5th	4th	5th
4	F.	†	†	M.	M.	†	F.
5	1150cc			1390cc	1530cc		
6	158	158	160	169	175*	180*	160
7	159	159	164	169	171	179	159
8	151	151	159	160	167	177	147
9	134	134	145	145	148		147
10	97	100	98	100	108	101	112
11	73	76	74	74	86		
12	98	101	94	110	115	115c	117
13	85	81	87	87	94	85c	
14	86; 113†	78; 109	98; 124	92; 112	100; 125	92; —	95; —
15	110; 110		117; 117	120; 120	126; 126	127; 127	114; 114
16	467	472	489	496	504	504	476
17	222; 245	208; 264	228; 261	221; 275	238; 266	244; 263	226; 250
18	338	354	341	353	354	376	323
19	120; 107; 111	115; 136; 103	121; 113; 107	130; 119; 101	128; 121; 105	—; —; 111	113; 109; 101
20	315; 290	—; 306c	343; 320	335; 316	310; 320	333; 312	315; 300
21	32; 26½	31; 29½	32; 28	34; 29	36; 34½		
22	126	121	127	137	146	139	139
23	100	96	102	104	117	106	109
24	91	93	100	98	99	96c	102
25	22½c	20½	25	25	24	25	28½
26	118; 68	99c; 61	109; 66	118c; 69	120; 72	126; 74	—; 68
27	51; 23½	45½; 25	49; 26	50; 27	52; 28	45; 27	53; 25½
28	37; 36	37; 34	38; 34½	37; 33	42; 36	38½; 36½	39; 33½
29	52; 33	49; 40	54; 40	50; —	52; 44	55; 36	54; —
30	34; 24	39; 24	40; 24	—; 25	44; 27	36; —	
31	15	14	18		19	17	
32	—; 47½	62; 47½	63; 48	—; 51	70; 54	66; —	—; 47
33	24c	13	13	13	13	18	
34		115; 91	113; 82	117; 96	131; 106		121; 103
35	60; 31½	61; 28	57; 30	66; 31	68; 33	65; 36	65; 31½†
36	102	101c	99	104c	110		
37	88	88	89	95	98		
38	91	94	98	107	109		
39	101	104	107	120	121		
40	110	112c	113	130	128		
41	127; 129		136; 137	146; 145	146; 147		
42	122			130	129		
43	68	68	63	72	68		
44	186	192	193	193	194	193	184
45	174	183	185	182	185	183	177
46	91; 93	89; 89	89; 93	98; 87	102; 91		
47	84°	84°	88½°	88°	89°	82½°	85°
48	4½	7½	17°	20°	14°	12½°	
49	13½°; 18°	19 ; 25°	29°; 38½°	30½°; 40°	25½°; 32½°	23°; 30½°	
50	84.27	84.27	88.41	85.79	86.54	76.53	92.45
51	79.87		82.92	86.39	85.38		
52	82.81	95.16	87.50	85.29	95.83		
53	129.67	106.45	109.00	120.40	121.21	131.25	
54	74.72	65.59	66.00	70.40	72.72	77.08	66.66
55	93.65	81.81	85.86	86.13	82.19	90.64	
56	53.96	50.41	51.96	50.36	49.31	53.23	48.92
57	46.07	54.94	53.06	54.00	53.84	60.00	48.11
58	97.29	91.89	90.78	89.18	85.71	94.80	85.89
59	73.07	81.63	74.07		84.61	64.86	
60	96.70	93.61	90.81	88.78	89.90		

* Not in sagittal plane at occiput.

TABLE I—Continued.

1	H, 22.	H, 23.	H, 24.	H, 25.	H, 26.	H, 27.	H, 28.
2							
3	4th?	4th	4th	5th	5th	5th	1st
4	?	?	M	M	M	?	?
5							
6	160	176	154	166*	155	163	*160
7	161	176	158	165c	156	164	157
8	155	165	150		150	153	158½
9		138	144	147	140c	136	132
10		100?	104		104		99
11		87	79	81c		72	72
12		113	103	112c	110	95	95
13			81	89c		86	76
14	89; —	86; 120	93c; —		85; 112	89; 111c	86; 107
15		115; 115	122; 122		112; 112	111; 111	110; 110
16	480c	498	484		467	483	460
17		254; 244	224; 260		210; 257	233; 250	203; 257
18		350	345		327c	350	328
19	125; 134; —	139; 107; 104	124; 121; 100	—; —; 96	108; 110; 109c		111; 117; 100
20		320; 307	345; 319		320; 296	318; 300	318; 287
21		38; 31	33½; 30½	37½; 33	—; 28	31; 28	36½; 30
22			129	141c		125	
23	106	104c	101	108c	101	105	89
24	104	105	95			95	79
25	21½		23	23		23	18
26	—; 68	108; 66	122; 72	125; 76		—; 75	92; 54
27	46; 26	51; —	50; 25	55; 27	48; 25½c	53c; 24	40; 22½
28	38½; 31½		†38; 35½	41; 37	38½c; 33	40; 38	35; 31
29	55; —	—; 38	49; 33	57; 36	—; 38	54; 34	38, 30
30		38; 23	38; 23	37; 23	39; —	34; 25	32; 23
31			17		13	14	9
32		63; 49	59; 52	63; 49		61; 44	—; 37
33		13	15			31	5c
34		122c; 100	114; 105	116; 99			94½; 77
35		68; 37	59; 29	66; 33	—; 31		42½; 23
36		113	109	113			86
37		99	89	99		97½	80
38		105	95	105	98c	97	85
39		120	108		105c	108	96
40		125	117		113c	114	106
41		139; 139	143; 146		129; 131c	134; 135	122; 124
42		132	140	134	124c		117
43		75	72?	72	66c	78	
44	197	201	201	198		206	172
45	184	193	190c	188	172c	193c	168
46		106; 93	90; 97	101; 93	94c; 83c	103; 95	82; 85
47	76°	84°	85°	84°		80°	88°
48		18°	21½°	23°		8°	9½°
49		28½°; 38°	34° ; 45°	35° ; 46½°		20°; 26°	18½°; 26½°
50		78.40	91.13	89.09	89.74	82.92	84.07
51		78.97	90.50		82.69	81.70	77.70
52		79.48	91.04	88.00		90.32	82.19
53		102.85	128.42				116.45
54	65.38	62.85	75.78			78.94	68.35
55			94.57	88.65			
56			55.81	53.19		60.00	
57	56.52		50.00	49.09	53.12	45.28	55.55
58	81.81		93.42	90.24	85.71	95.00	88.57
59			71.42	63.15		62.96	78.94
60		94.28	93.68	94.28		100.51	94.11

*Not strictly in sagittal plane. †Not parallel to either border

TABLE I—Continued.

1	II, 29.	II, 32.*	II, 33.	II, 34.	II, 35.	II, 36.	II, 37.
2							
3	2nd	4th†	4th	6th	5th	6th	4th
4	?	M.	?	M.	?	F.	?
5							
6	149	† 148	164	169	† 157	† 160	165
7	151	148	166c	171	157	159	166
8	145	139	153†	164	144	157	162
9	141	136c	145	143	135	135	143
10	95		114			100	
11	45		81†	84		74	
12	97	110	106	105	102	104	141
13	78	80†	83†	85			92c
14	90; 113	85; 112	92c; —	92; 118		90; —	96c; 120†
15	112; 112	121; 121	113; 113	119; 119	112; 112	117; 117	124; 124
16	463	418	495	499	461	472	492
17	208; 255	215; 233	230; 295	232c; 269c	207; 254		241; 251
18	323	338	361	361	333	343c	366c
19	114; 92; 117	120; 124; 94	133; 117; 111	127c; 113; 121	123; 115; 95		135; 116; 115c
20	333; 300	334; 311	327; 311	337; 313	319; 296	322; —	350; 326
21	35½; 30		31; ‡32	34; 30½		34; 28	—; 35
22	114	122	133				
23	93	99	106c	107c		101c	
24	90	92	99	98			
25	21	24c	30c		24		
26	98; 56	—; 64	—; 65c		116; 71		111c; 66
27	42; 22½	47; 24	45; 25½	55; 24½	48; 25		47½; 26
28	35; 32	38c; 36				36½c; 36½	38; 36
29	43; 33	48; —	53; 40	50; —	53; 37		55; 37
30			38; 24		38; 23		—; 25
31	11		21				16
32	61; 41	—; 44	64; 47	—; 49	—; 47	—; 51	61; —
33		6	21c	10c	23		25c
34	103; 70	110; 95				119; 92	113; 97
35	46; 30	58; 27	65; 32	63; 32	66; 30	57; 30	61; 35
36	86				105c		
37	80	92	96c	§93	97†		102†
38	85	101c	95c	102	98	95c	95
39	95	113c	108c	114	109	106	106
40	102	119c	119†	119	117	111	115
41	125; 131	144c; 148c	137; 137	43; 143	136; 138	—; 136	144; 143
42	132	130c	136	138	128	124	135c
43	60	64c		72		66	69
44	182c	188	202c		202c		202†
45	175	181	193	194	184	182	190†
46	81; 85	93; 61	97; 101	95; 84	99; 89	94; 81	—; 95c
47		85°	79°		77½		80°
48	11		11½°			12°	
49	20°; 28°		23½°; 30°	23½°; 31°		21½°; 28°	
50	93.37	91.89	87.34	83.62	85.92	84.90	86.14
51	82.78	97.29	82.53	83.62	86.62		86.74
52	84.50		103.22	89.70		82.35	
53	108.88						
54	62.22	69.56	65.65				
55	85.96						
56	49.12	52.45	48.87				
57	53.17	51.06	56.66	44.54	52.08	59.34	54.73
58	91.42‡	94.73				100.00	94.73
59	77.90		75.47		69.81		67.67
60	94.11	91.08	101.05	91.17	98.36		107.36

The conditions of Nos. 30 and 31 admitted of so few measurements that these are not tabulated.
† Not in sagittal plane at occiput.
‡ Taken at first permanent molars, the only molars erupted.
§ General absorption of the alveoli. This is practically a basilo-subnasal line.

TABLE I—Continued.

1	H. 38.	H. 39.	H. 40.	H. 41.	H. 42.	H. 43.	H. 44.
2							
3	4th	4th	4th	4th	5th	4th	4th
4	?	F.	?	M.	?	?	?
5							
6			*158	161	176		168
7		150	156	162	175		168
8		148	149	167	167		168
9	138	142	135	149	144		143
10	106	106	103			93	111
11	82		78	84c		80	
12	111	104c	105	114		107	108
13	88		81		81?	86	
14			86; —	91; 116c	92; —	93; —	82; 113
15	123; 123	—; 117	113; 113	120; 120	116; 116		120; 120
16			465	492	509		493
17			211; 254	231; 261	241; 268		240; 253
18		329	329c	349c	361c		348c
19		118; 118; 93	114c; 116c; 99;	116; 127; 106c	125; 132; 104c		127; 117; 104c
20	330; —	331; 305	312; 290	340; 311c	326; 311		333; 308
21	34; 31		35½; 30		—; 27	36; 29	
22			123	136		133	
23			101	104	105	100	
24			93	98		92	
25						19	
26			114; 65	115; 64	123; 75	117; 71	—; 69c
27			45c; 23	48c; 25½	52; 27	52; 23	51c; 29
28			38; 36½	37½; 35½		36; 33	
29			50; 38	50; 40		57; 40	50; —
30			40; 19	40; 25	—; 27	38; 22	40; —
31			16	17		19	
32			60; 45	64; 48		62; 46	—; 52
33			12	11	16	15½	13
34			108; 93	122; 98		115; 90	—; 116
35	69; 34	61; 29	53; 29	67; 35	71; 33	64; 33½	62; 32
36			99	115	108c	106	
37			91	94	102	91	93
38			96c	97	109	92	100c
39			110	110	119	106	116
40			118	118	127	116	122
41	143c; 141		132c; 134	137; 139	140; 142		143; 143
42	132		127	116	133		
43	73		69		70	67	80
44			183	172	199		177
45				164c	188		170
46	—; 92		93; 83	99; 80	108c; 90	93; —	94; 86
47			83°	84°	84°	87°	86½°
48			14°			14½°	
49			22½°; 30°			26°; 34½°	
50		94.66	86.53	91.97	82.28		85.11
51			84.61	84.56	80.00		
52	91.17		84.50			80.55	
53			122.58	117.34		127.17	
54			69.89	65.30		77.17	
55			92.68	84.55		87.97	
56			52.84	47.05		53.38	
57			51.11	53.12	51.92	44.23	56.86
58			96.05	94.66		91.66*	
59			76.00	80.00		71.05	
60			94.79	96.90	93.57	98.91	93.00

*Not in sagittal plane at occiput.

TABLE 1—Continued.

1	H. 45.	H. 46.	H. 47.	H. 49.	H. 50.	H. 51.	H. 52.
2							
3	4th	3d	4th	4th	2d	2d	4th
4	F.	†	†	†	†	†	†
5							
6	161	146	*153		150	145	*160
7	163	148c	159		150	148	160
8	154	139	144		145	141	161
9	148	145	147		136	139	137
10			98		92	105	103
11		81	88		79		
12		104	109	108	102	96	111
13	88				79	77	
14	94; —	95; 114c	93; —		88; 108c	87; 114	91; 119
15	116; 116	113; 113	125; 125		111; 111	112; 112	118; 118
16	497	468	483c		451	456	478
17	221; 276	209; 259	220c; 263		203; 248	194; 262	239; 239
18	335		344		324	330c	342
19	120; 107c; 108c	—; 100; 108	123; 121; 97	129; 120; —	119; 107; 98	115; 110; 105	120; 114; 108
20	339; 310	322?; 300	350; 324		307; 290	318; 300	322; 302
21		32c; 33c	32; 31		38½; 28½	—; 30	
22	129						
23	104	104			93	91	100
24	96	91		98c	92	85	
25				27½		20	
26	109; 66			—; 71	—; 60	—; 57	—; 71
27	47; 24½			48; 28½?	45; 24	42½; 20	53; 24
28	38; 33½			36; 34		33; 30	
29	53; 38	49; 38		50; 38	42; 32½	45; —	—; 36
30	42; 25			41; —	—; 27		36; —
31	14			16	11	8	
32	65; 54			65; —	59	57; 42	62; —
33	17	20			10	10	
34	122; 99		114; 97				
35	60; 34	54; 30	61; 32	60; 38			
36	110						
37	99	95			82	81	
38	101		102		89	87	
39	108	100c	111		101	98	
40	119	108	120		111	106	
41	135; 136	123; 126	144; 144		131; 132	131; 132	
42			136		123	125	
43		59	60?		68c	59c	
44	190	188			176	182	173
45	190	178			168	175	164
46	100; 90	94; 81	91; 81		83; 81	82; 77	97?; 78?
47	82°	82½°		83°	85°	86°	85°
48		14½°			14½°		13°
49		28°; 34½°			24½°; 35°		24°; 30°
50	90.79	97.97	92.45		90.66	93.91	85.62
51	82.82	83.10	90.56		87.33	88.51	86.25
52		103.12	96.87		71.02		
53	113.54						
54	68.75				65.21	67.05	
55	84.49						
56	51.16						
57	52.13			59.37	53.33	47.05	45.28
58	88.15			94.44		90.90	
59	71.69	77.55		76.00	76.19		
60	98.01				92.13	93.10	

* Not in sagittal plane at occiput.
† This is the true maximum circumference; the circumference at the maximum occipital point (which coincides with the obelion) is 471.
‡ Taken at the first permanent molar, the second not being erupted.

No. 48 is not included in this table, because its condition did not admit of many measurements.

TABLE I—Concluded.

1	H. 53.	H. 54.	H. 55.	H. 56.	H. 57.
2					
3	5th? ?	4th ?	5th ?	5th ?	4th F.
4					
5	1, 120cc				
6	*149	145	188	*159	*152
7	148	148	188	158	150
8	145	146	186	152	146c
9	136	134	148	143	142
10	100	101c	107		
11	77		74	85c	
12	98	97	104	115c	101
13	76?				
14	83; 115	89; —	100; —	92; —	91
15	113; 113	113; 113	127; 127	113; 113	121; 121
16	450	450	530c	476	464
17	201; 249	206; 244	275; 255	229; 247	219; 245
18	340	330			325
19	122; 115; 103	117; 113; 100		120; 113; —	120; 111; 94
20	330; 303	320; 301	352; 337	323; 302	322; 302
21	31½; 28½				38½; —
22				130	
23	96	101	113	102	102
24					
25				24	
26		111; 67		106; 64	104; 62
27		48; —		46; 24½	45; 27½
28	34½; 32			38; 35	37; 32½
29		—; 36		52; 38	52; 40
30		—; 24		38; —	40; 27
31					15
32				—; 48	63; 46
33		25		15	20c
34		108; 96		120c; 87	
35		61; 26		56; 32	53; 30
36					103
37					90
38	92				89
39	105				98
40	118				109
41	137; 137			132c; —	128; 129
42	123				123
43	61?				63
44		182		186	183
45	167c	170		178	172
46	—; 76	91; 90			91; 85
47		84°		84°	82°
48	91°				114°
49	20°; 26°				22°; 30°
50	91.89	90.54	78.72	90.50	94.66
51	92.56	87.16		83.54	85.33
52	90.47				
53					
54					
55				81.53	
56				49.23	
57				53.26	61.11
58	92.75			92.10	87.85
59				73.07	76.92
60					101.12

*Not in sagittal plane at occiput.

TABLE II.—*Ordination of 48 cephalic indices.—Salado.*

	No. of skull.	Index		No. of skull.	Index.		No. of skull.	Index.
1	H. 23	78.40	17	H. 40	86.53	33	H. 50	90.56
2	H. 55	78.72	18	H. 19	86.54	34	H. 45	90.79
3	H. 12	78.97	19	H. 33	87.34	35	H. 24	91.13
4	H. 42	82.28	20	H. 9	87.41	36	H. 32	91.89
5	H. 27	82.92	21	H. 5	87.50	37	H. 53	91.89
6	H. 34	83.62	22	H. 13	87.58	38	H. 41	91.97
7	H. 28	84.07	23	H. 11	87.89	39	H. 21	92.45
8	H. 15	84.27	24	H. 8	88.07	40	H. 47	92.45
9	H. 16	84.27	25	H. 17	88.41	41	H. 29	93.37
10	H. 36	84.90	26	H. 14	88.55	42	H. 6	93.71
11	H. 44	85.11	27	H. 25	89.09	43	H. 51	93.91
12	H. 52	85.62	28	H. 26	89.74	44	H. 39	94.66
13	H. 18	85.79	29	H. 2	90.00	45	H. 57	94.66
14	H. 7	85.80	30	H. 10	90.50	46	H. 4	96.09
15	H. 35	85.92	31	H. 56	90.50	47	H. 3	96.17
16	H. 37	86.14	32	H. 54	90.54	48	H. 46	97.97

Variation, 19.57. Theoretical mean of variation, 88.19. Skull nearest to mean, H. 8. Average, 88.47.

TABLE III.—*Seriation of 48 cephalic indices.—Salado.*

	Index.	Number of skulls.		Index.	Number of skulls.
1	77 to 78	1	12	88	3
2	78	2	13	89	2
3	79	0	14	90	6
4	80	0	15	91	4
5	81	0	16	92	2
6	82	2	17	93	3
7	83	1	18	94	2
8	84	4	19	95	0
9	85	5	20	96	2
10	86	3	21	97 to 98	1
11	87	5			

Maximum of frequency, 90.

TABLE IV.—*Ordination of 16 cephalic indices of apparently normal skulls.—Salado.*

	No.	Index.		No.	Index.
1	H. 23	78.40	9	H. 40	86.53
2	H. 12	78.97	10	H. 19	86.54
3	H. 34	83.62	11	H. 25	89.09
4	H. 15	84.27	12	H. 26	89.74
5	H. 36	84.90	13	H. 54	90.54
6	H. 44	85.11	14	H. 21	92.45
7	H. 18	85.79	15	H. 39	94.66
8	H. 7	85.80	16	H. 57	94.66

Variation, 16.20. Theoretical mean of variation, 86.53. Skulls nearest to mean, H. 7 and H. 40. Average, 86.94.

No. H. 55, an apparently normal skull, of which the vault only is preserved, has a normal index of 78.72, but it is aberrant as regards the rest of the group by reason of its much greater size and different configuration.

No. H. 23, having lowest cephalic index, has next to lowest vertico-transverse index. The lowest vertico-transverse index is in the skull of a child.

TABLE V.—*Seriation of 16 cephalic indices of apparently normal skulls.—Salado.*

	Index.	Number of skulls.		Index.	Number of skulls.
1	78 to 79	2	10	87	0
2	79	0	11	88	0
3	80	0	12	89	2
4	81	0	13	90	1
5	82	0	14	91	0
6	83	1	15	92	1
7	84	2	16	93	0
8	85 to 86	3	17	94 to 95	2
9	86	2			

Maximum of frequency, 85 to 86.

TABLE VI.—*Of the cephalic indices of all the skulls.—Salado.*

Number of indices	48	Per cent.
Number below 80.00	3	6.25
Number from 80.00 to 89.99	25	52.09
Number from 90.00 up	20	41.66
	48	100.00

Minimum index, 77.65. Maximum index, 97.97.

TABLE VII.—*Ordination of 47 length-breadth indices (German).—Salado.*

	Number of skull.	Index.		Number of skull.	Index.		Number of skull.	Index.
1	H. 23	78.40	17	H. 35	85.98	33	H. 21	91.87
2	H. 55	78.72	18	H. 37	86.66	34	H. 32	91.89
3	H. 12	78.97	19	H. 9	86.84	35	H. 45	91.92
4	H. 42	81.81	20	H. 5	87.50	36	H. 10	92.25
5	H. 28	82.50	21	H. 11	87.89	37	H. 54	92.41
6	H. 27	83.43	22	H. 13	88.15	38	H. 41	92.54
7	H. 36	84.37	23	H. 33	88.41	39	H. 57	93.42
8	H. 19	84.57	24	H. 14	88.55	40	H. 24	93.50
9	H. 34	84.61	25	H. 25	88.55	41	H. 6	93.71
10	H. 15	84.81	26	H. 8	89.44	42	H. 29	94.63
11	H. 16	84.81	27	H. 56	89.93	43	H. 51	95.86
12	H. 44	85.11	28	H. 26	90.32	44	H. 47	96.07
13	H. 40	85.44	29	H. 17	90.62	45	H. 3	96.17
14	H. 52	85.62	30	H. 50	90.66	46	H. 4	98.63
15	H. 18	85.79	31	H. 53	91.27	47	H. 46	99.31
16	H. 7	85.80	32	H. 2	91.72			

Variation, 20.91. Theoretical mean of variation, 88.86. Skulls nearest to mean, H. 14 and H. 25. Average, 88.75.

TABLE VIII.—*Ordination of 38 vertico-longitudinal indices.—Salado.*

	Number of skull.	Index.		Number of skull.	Index.		Number of skull.	Index.
1	H. 23	78.79	14	H. 56	83.54	27	H. 37	86.74
2	H. 15	79.87	15	H. 34	83.62	28	H. 57	87.16
3	H. 42	80.00	16	H. 41	84.56	29	H. 50	87.33
4	H. 27	81.70	17	H. 40	84.61	30	H. 51	88.51
5	H. 33	82.53	18	H. 11	84.71	31	H. 3	88.59
6	H. 26	82.69	19	H. 44	85.11	32	H. 9	89.40
7	H. 29	82.78	20	H. 4	85.33	33	H. 2	90.00
8	H. 45	82.82	21	H. 57	85.33	34	H. 24	90.50
9	H. 17	82.92	22	H. 49	85.38	35	H. 47	90.56
10	H. 46	83.10	23	H. 52	86.25	36	H. 13	91.50
11	H. 14	83.13	24	H. 1	86.36	37	H. 10	91.77
12	H. 5	83.33	25	H. 18	86.39	38	H. 53	92.56
13	H. 7	83.33	26	H. 35	86.62			

Variation, 13.59. Theoretical mean of variation, 85.76. Skull nearest to mean, H. 19. Average. 83.87.

H. 28, a child's skull, with index of 77.70, and H. 32, aberrant in size and form (see § 11), with index of 97.29, are excluded from the above ordination.

TABLE IX.—*Seriation of 39 vertico-longitudinal indices.—Salado.*

Index.	Number of skulls.	Index.	Number of skulls.
78 to 79	1	88	2
79	1	89	1
80	1	90	3
81	1	91	2
82	5	92	1
83	6	93	0
84	3	94	0
85	4	95	0
86	5	96	0
87	2	97 to 98	1

Maximum of frequency, 83; 97 to 98, one skull, not included in the ordination.

TABLE X.—*Ordination of 11 vertico-longitudinal indices of apparently normal skulls.—Salado.*

	Number of skull.	Index.		Number of skull.	Index.
1	H. 23	78.97	7	H. 44	85.11
2	H. 15	79.87	8	H. 57	85.33
3	H. 26	82.69	9	H. 19	85.38
4	H. 7	83.33	10	H. 18	86.36
5	H. 34	83.62	11	H. 54	87.16
6	H. 40	84.61			

TABLE XI.—*Seriation of 11 vertico-longitudinal indices of apparently normal skulls.—Salado.*

Index.	Number of skulls.	Index.	Number of skulls.
78 to 79	1	83	2
79	1	84	1
80	0	85	3
81	0	86	1
82	1	87 to 88	1

TABLE XII.—*Ordination of all the skulls in which the vertico-longitudinal index exceeds the cephalic, showing excess in per cent of greatest length.—Salado.*

	No.	Excess.		No.	Excess.
1	H. 18	0.50	6	H. 35	0.70
2	H. 23	0.57	7	H. 10	1.20
3	H. 37	0.60	8	H. 9	1.99
4	H. 52	0.63	9	H. 13	3.92
5	H. 53	0.67	10	H. 32	5.40

Variation, 4.90. Theoretical mean of variation, 2.95. Skulls nearest to mean, H. 9, and H. 13. Skulls H. 18 and H. 23 are from the apparently normal group.

TABLE XIII.—*Seriation of all the skulls in which the vertico-longitudinal index exceeds the cephalic, showing excess in per cent of greatest length.—Salado.*

	Excess.	Number of skulls.		Excess.	Number of skulls.
1	0 to 1	6	4	3	1
2	1	2	5	4	0
3	2	0	6	5 to 6	1

TABLE XIV.—*Ordination of vertico-transverse indices.—Salado.*

	No. of skull.	Width.	Height.	Index.		No. of skull.	Width.	Height.	Index.
1	H. 46	14.5	12.3	84.82	21	H. 40	13.5	13.2	97.77
2	H. 4	14.5	12.8	88.27	22	H. 47	14.7	14.4	97.95
3	H. 29	14.1	12.5	88.65	23	H. 27	13.6	13.4	98.52
4	H. 57	14.2	12.8	90.14	24	H. 19	14.8	14.6	98.64
5	H. 45	14.8	13.5	91.21	25	H. 24	14.4	14.3	99.30
6	H. 41	14.9	13.7	91.94	26	H. 2	14.4	14.4	100.00
7	H. 26	14.0	12.9	92.14	27	H. 34	14.3	14.3	100.00
8	H. 56	14.3	13.2	92.30	28	H. 44	14.3	14.3	100.00
9	H. 28	13.2	12.2	92.42	29	H. 18	14.5	14.6	100.68
10	H. 17	14.5	13.6	93.79	30	H. 37	14.3	14.4	100.69
11	H. 14	14.7	13.8	93.87	31	H. 23	13.8	13.9	100.72
12	H. 51	13.9	13.1	94.24	32	H. 52	13.7	13.8	100.72
13	H. 33	14.5	13.7	94.48	33	H. 53	13.6	13.7	100.73
14	H. 15	13.4	12.7	94.77	34	H. 35	13.5	13.6	100.74
15	H. 5	14.7	14.0	95.23	35	H. 10	14.3	14.5	101.39
16	H. 54	13.4	12.9	96.26	36	H. 9	13.2	13.5	102.27
17	H. 50	13.6	13.1	96.32	37	H. 38	13.8	14.3	103.62
18	H. 11	13.8	13.3	96.37	38	H. 13	13.4	14.0	104.47
19	H. 7	13.9	13.5	97.12	39	H. 32	13.6	14.4	105.88
20	H. 42	14.4	14.0	97.22					

TABLE XV.—*Of the vertico-transverse indices of all the skulls.—Salado.*

		Per cent.
Number of indices	40	
Number below 80.00	3	7.5
Number from 80.00 to 89.99	30	75.0
Number from 90.00 up	7	17.5
	40	100.0

Minimum index, 77.70; maximum index, 97.29. Neither of these two indices come in the normal series, as the minimum is that of a child, the maximum aberrant. They therefore do not appear in the ordination.

TABLE XVI.—*Ordination of the apparently normal skulls, with reference to the differences between their respective cephalic and vertico-transverse indices, expressed in per cent of the greatest length.—Salado.*

[The sign + indicates that the cephalic index is greater than the vertico-transverse. The sign − indicates that the vertico-transverse index is greater than the cephalic.]

	No.	Difference.		No.	Difference.
1	H. 23	−.57	7	H. 7	+2.47
2	H. 18	−.50	8	H. 54	+3.38
3	H. 34	.00	9	H. 15	+4.40
4	H. 44	.00	10	H. 26	+7.05
5	H. 19	+1.16	11	H. 57	+9.33
6	H. 40	+1.92			

Variation, 9.90. Theoretical mean of variation, 4.38. Skull nearest to mean, H. 15. This skull then shows what may be arithmetically regarded as a typical relation of vertico-transverse and cephalic indices.

TABLE XVII.—*Ordination of mixed indices.—Salado.*

	No. of skull.	Vertico-transverse index.	Vertico-longitudinal index.	Mixed index.
1	H. 46	81.82	83.10	83.96
2	H. 29	88.45	82.78	85.71
3	H. 4	88.27	85.33	86.80
4	H. 45	91.21	82.82	87.04
5	H. 26	92.14	82.69	87.14
6	H. 15	94.97	79.87	87.42
7	H. 57	90.14	85.33	87.73
8	H. 56	92.30	83.54	87.92
9	H. 41	91.94	84.56	88.25
10	H. 17	93.79	82.92	88.35
11	H. 33	94.48	82.53	88.50
12	H. 14	93.87	83.13	88.50
13	H. 42	97.22	80.00	88.61
14	H. 5	95.23	83.33	89.28
15	H. 23	100.72	78.79	89.75
16	H. 27	98.52	81.70	90.11
17	H. 7	97.12	83.33	90.22
18	H. 11	96.37	84.71	90.54
19	H. 40	97.77	84.61	91.19
20	H. 51	94.24	88.51	91.37
21	H. 54	96.26	87.16	91.71
22	H. 34	100.00	83.62	91.81
23	H. 50	96.32	87.33	91.82
24	H. 19	98.64	85.58	92.01
25	H. 44	100.00	85.11	92.55
26	H. 52	100.72	86.25	93.48
27	H. 18	100.68	86.39	93.53
28	H. 35	100.74	86.62	93.68
29	H. 37	100.69	86.74	93.71
30	H. 47	97.95	90.56	94.25
31	H. 24	99.30	90.50	94.90
32	H. 2	100.00	90.00	95.00
33	H. 9	102.27	89.40	95.83
34	H. 10	101.39	91.77	96.58
35	H. 53	100.73	92.56	96.64
36	H. 13	104.47	91.50	97.98
	Average..	96.46	85.40	90.94

TABLE XVIII.—*Ordination of 29 angles of Daubenton.—Salado.*

	Number of skull.	Angle.			Number of skull.	Angle.	
		°	′			°	′
1	H. 15	4	30	16	H. 19	14	00
2	H. 16	7	30	17	H. 10	14	00
3	H. 27	8	00	18	H. 43	14	30
4	H. 28	9	30	19	H. 46	14	30
5	H. 53	9	30	20	H. 50	14	30
6	H. 6	10	00	21	H. 3	15	00
7	H. 8	10	30	22	H. 14	15	30
8	H. 5	11	00	23	H. 7	16	00
9	H. 29	11	00	24	H. 17	17	00
10	H. 33	11	30	25	H. 10	18	30
11	H. 57	11	30	26	H. 23	18	30
12	H. 36	12	00	27	H. 18	20	00
13	H. 20	12	30	28	H. 24	21	30
14	H. 34	13	00	29	H. 25	23	00
15	H. 52	13	00				

Variation, 18° 30′. Theoretical mean, 13° 45′. Skulls nearest to mean, H. 19 and H. 40. Average, 13° 30′

TABLE XIX.—*Seriation of 29 angles of Daubenton.—Salado.*

	Angle.	Number of skulls.		Angle.	Number of skulls.
1	4° to 5°	1	11	14°	5
2	5	0	12	15	2
3	6	0	13	16	1
4	7	1	14	17	1
5	8	1	15	18	2
6	9	2	16	19	0
7	10	2	17	20	1
8	11	4	18	21	1
9	12	2	19	22	0
10	13	2	20	23 to 24	1

Maximum of frequency, 14°.

TABLE XX.—*Ordination of 29 occipital angles.— Salado.*

	No. of skull.	Angle.		No. of skull.	Angle.
		° ′			° ′
1	H. 15	13 30	16	H. 3	24 00
2	H. 28	18 30	17	H. 52	24 00
3	H. 6	19 00	18	H. 50	24 30
4	H. 16	19 00	19	H. 14	25 00
5	H. 5	20 00	20	H. 19	25 30
6	H. 27	20 00	21	H. 43	26 00
7	H. 29	20 00	22	H. 7	27 30
8	H. 53	20 00	23	H. 46	28 00
9	H. 8	21 30	24	H. 23	28 30
10	H. 56	21 30	25	H. 17	29 00
11	H. 57	22 00	26	H. 10	30 00
12	H. 40	22 30	27	H. 18	30 30
13	H. 20	23 00	28	H. 24	34 00
14	H. 33	23 30	29	H. 25	35 00
15	H. 34	23 30			

Variation, 21° 30′. Theoretical mean, 24° 15′. Skulls nearest to mean, H. 3, H. 52, H. 50 Average, 24° 6′.

TABLE XXI.—*Seriation of 29 occipital angles.—Salado.*

	Angle.	Number of skulls.		Angle.	Number of skulls.
1	13° to 14°	1	13	25°	2
2	14	0	14	26	1
3	15	0	15	27	1
4	16	0	16	28	2
5	17	0	17	29	1
6	18	1	18	30	2
7	19	2	19	31	0
8	20	4	20	32	0
9	21	2	21	33	0
10	22	2	22	34	1
11	23	3	23	35 to 36	1
12	24	3			

Maximum of frequency, 20°

TABLE XXII.—*Ordination of 29 basilar angles.—Salado.*

	No. of skull.	Angle.		No. of skull.	Angle.
		′			′
1	II. 15	18 00	16	II. 34	31 00
2	II. 6	24 00	17	II. 3	31 30
3	II. 16	25 00	18	II. 19	32 30
4	II. 5	26 00	19	II. 14	33 30
5	II. 27	26 00	20	II. 43	34 30
6	II. 28	26 30	21	II. 46	34 30
7	II. 53	26 30	22	II. 50	35 00
8	II. 29	28 00	23	II. 7	36 30
9	II. 36	28 00	24	II. 10	38 00
10	II. 8	28 30	25	II. 23	38 00
11	II. 33	30 00	26	II. 17	38 30
12	II. 40	30 00	27	II. 18	40 00
13	II. 52	30 00	28	II. 24	45 00
14	II. 20	30 30	29	II. 25	46 30
15	II. 57	30 30			

Variation, 28° 30′. Theoretical mean, 32° 15′. Skull nearest to mean, II. 19. Average, 31° 48′.

TABLE XXIII.—*Seriation of 29 basilar angles.—Salado.*

	Angle.	Number of skulls.		Angle.	Number of skulls.
1	18° to 19°	1	16	33°	1
2	19	0	17	34	2
3	20	0	18	35	1
4	21	0	19	36	1
5	22	0	20	37	0
6	23	0	21	38	3
7	24	1	22	39	0
8	25	1	23	40	1
9	26	4	24	41	0
10	27	0	25	42	0
11	28	3	26	43	0
12	29	0	27	44	0
13	30	5	28	45	1
14	31	2	29	46 to 47	1
15	32	1			

Maximum of frequency, 30°.

TABLE XXIV.—*Average cranial capacity of 12 small series of skulls in the general collection of the Army Medical Museum.*

Races or tribes.	Total number of skulls.	Average capacity.
Sandwich Islanders	6	1491
Mongolians (2 Japanese, 2 Chinese)	4	1465
Siouan (4 Sioux, 4 Poncas, 2 Minnetarees)	10	1463
New Zealanders	4	1453
American negroes	6	1383
North American Indians (11 tribes, exclusive of Saladoans)	47	1374
Pah-Utes	7	1367
Eskimos (4 Alaska, 6 Greenland)	10	1357
Apaches	6	1331
Ancient Californians	10	1323
Navajos	6	1315
Peruvians (1 artificially elongated, 3 with antero-posterior compression, 2 normal, 1 plagio-cephalic)	10	1295

TABLE XXV.—*Length in millimetres of 28 pteria.—Salado.*

No. of skull.	Right side.	Left side.	No. of skull.	Right side.	Left side.
H. 7	.....	11	H. 19	10	12
H. 10	10	9	H. 22	.....	9
H. 11	.....	9	H. 24	.....	8
H. 12	.....	16	H. 28	13	12
H. 13	5	.....	H. 29	13	16
H. 14	.....	12	H. 38	10	.....
H. 15	.....	3	H. 40	.....	6
H. 16	11	12	H. 42	19	.....
H. 17	20	18	H. 50	.....	14
H. 18	15	10	H. 51	16	16

TABLE XXVI.—*Ordination of 19 facial indices according to Virchow.—Salado.*

	No. of skull.	Index.		No. of skull.	Index.
1	H. 23	102.85	11	H. 11	118.00
2	H. 16	106.45	12	H. 18	120.40
3	H. 29	108.88	13	H. 19	121.21
4	H. 17	109.00	14	H. 40	122.58
5	H. 5	110.67	15	H. 43	127.17
6	H. 1	111.65	16	H. 14	127.55
7	H. 4	112.24	17	H. 24	128.42
8	H. 45	113.54	18	H. 15	129.67
9	H. 28	116.45	19	H. 20	131.25
10	H. 31	117.34			

Variation, 28.40. Theoretical mean of variation, 117.05. Skull nearest to mean and median of ordination, H. 41. Average, 117.64.

TABLE XXVII.—*Seriation of 19 facial indices according to Virchow.—Salado.*

Index.	Number of skulls.	Index.	Number of skulls.	Index.	Number of skulls.
102 to 103	1	112	1	122	1
103	0	113	1	123	0
104	0	114	0	124	0
105	0	115	0	125	0
106	1	116	1	126	0
107	0	117	1	127	2
108	1	118	1	128	1
109	1	119	0	129	1
110	1	120	1	130	0
111	1	121	1	131 to 132	1

Maximum of frequency, 127. The seriation is so incoherent that the discussion of variation as dependent on it has little significance.

TABLE XXVIII.—*Ordination of 34 upper facial indices according to Virchow.—Salado.*

	No. of skull.	Index.		No. of skull.	Index.		No. of skull.	Index.
1	H. 29	62.22	13	H. 51	67.05	25	H. 19	72.72
2	H. 23	62.85	14	H. 4	67.34	26	H. 8	72.92
3	H. 50	65.21	15	H. 9	68.31	27	H. 3	73.71
4	H. 41	65.39	16	H. 28	68.35	28	H. 15	74.72
5	H. 22	65.38	17	H. 2	68.42	29	H. 24	75.78
6	H. 16	65.59	18	H. 45	68.75	30	H. 10	76.34
7	H. 33	65.65	19	H. 6	69.32	31	H. 20	77.08
8	H. 7	66.00	20	H. 32	69.56	32	H. 43	77.17
9	H. 17	66.00	21	H. 40	69.89	33	H. 27	78.94
10	H. 5	66.01	22	H. 18	70.40	34	H. 14	79.59
11	H. 21	66.66	23	H. 11	71.00			
12	H. 13	67.00	24	H. 1	72.72			

Variation, 17.37. Theoretical mean of variation, 70.90. Skull nearest to mean, H. 11. Average, 69.82.

TABLE XXIX.—*Seriation of 34 upper facial indices according to Virchow.—Salado.*

Index.	No. of skulls.	Index	No. of skulls.
62 to 63	2	71	1
63	0	72	3
64	0	73	1
65	5	74	1
66	4	75	1
67	3	76	1
68	4	77	2
69	3	78	1
70	1	79 to 80	1

Maximum of frequency, 65.

TABLE XXX.—*Ordination of 17 facial indices according to Kollmann.—Salado.*

	No. of skull.	Index.		No. of skull.	Index.
1	H. 56	81.53	10	H. 43	87.97
2	H. 16	81.81	11	H. 25	88.65
3	H. 19	82.19	12	H. 20	90.64
4	H. 45	84.49	13	H. 11	91.47
5	H. 41	84.55	14	H. 40	92.68
6	H. 17	85.86	15	H. 15	93.65
7	H. 29	85.96	16	H. 24	94.57
8	H. 18	86.13	17	H. 14	97.65
9	H. 1	86.50			

Variation, 16.12. Theoretical mean of variation, 89.59. Skull nearest to mean, H. 25. Average, 88.01.

TABLE XXXI.—*Seriation of 17 facial indices according to Kollmann.—Salado.*

	Index.	Number of skulls.		Index.	Number of skulls.
1	81 to 82	2	10	90	1
2	82	1	11	91	1
3	83	0	12	92	1
4	84	2	13	93	1
5	85	2	14	94	1
6	86	2	15	95	0
7	87	1	16	96	0
8	88	1	17	97 to 98	1
9	89	0			

Maximum of frequency, 84, 85, and 86.

TABLE XXXII.—*Ordination of 27 upper facial indices according to Kollmann.—Salado.*

	No. of skull.	Index.		No. of skull.	Index.
1	H. 41	47.05	15	H. 13	52.75
2	H. 33	48.87	16	H. 10	52.81
3	H. 21	48.92	17	H. 25	53.19
4	H. 29	49.12	18	H. 20	53.23
5	H. 56	49.23	19	H. 43	53.38
6	H. 19	49.31	20	H. 1	53.96
7	H. 18	50.36	21	H. 15	53.96
8	H. 7	50.38	22	H. 9	54.76
9	H. 8	50.58	23	H. 11	55.03
10	H. 16	50.41	24	H. 24	55.81
11	H. 45	51.15	25	H. 10	56.34
12	H. 3	51.43	26	H. 27	60.00
13	H. 17	51.96	27	H. 14	60.93
14	H. 32	52.15			

Variation, 13.88. Theoretical mean of variation, 53.99. Skulls nearest to mean, H. 1 and H. 15. Average, 52.48.

Excluding H. 27 and H. 14 the variation is 9.27, the mean 51.69, the skull nearest the mean H. 3, and the average 51.85.

TABLE XXXIII.—*Seriation of 27 upper facial indices according to Kollmann.—Salado.*

	Index.	Number of skulls.		Index.	Number of skulls.
1	47 to 48	1	8	54	1
2	48	2	9	55	2
3	49	3	10	56	1
4	50	4	11	57	0
5	51	3	12	58	0
6	52	3	13	59	0
7	53	5	14	60 to 61	2

Maximum of frequency, 53.

TABLE XXXIV.—*Ordination of 44 German profile angles.—Salado.*

	No. of skull.	Angle.		No. of skull.	Angle.		No. of skull.	Angle.	
		°	′		°	′		°	′
1	H. 22	76	00	16	H. 46	82	30	31	H. 32	85	00
2	H. 4	77	00	17	H. 24	83	00	32	H. 50	85	00
3	H. 35	77	30	18	H. 40	83	00	33	H. 52	85	00
4	H. 2	78	00	19	H. 49	83	00	34	H. 6	86	00
5	H. 9	78	00	20	H. 7	84	00	35	H. 14	86	00
6	H. 33	79	00	21	H. 15	84	00	36	H. 51	86	00
7	H. 1	79	30	22	H. 16	84	00	37	H. 3	86	30
8	H. 10	80	00	23	H. 23	84	00	38	H. 44	86	30
9	H. 11	80	00	24	H. 25	84	00	39	H. 5	87	00
10	H. 27	80	00	25	H. 41	84	00	40	H. 43	87	00
11	H. 37	80	00	26	H. 42	84	00	41	H. 18	88	00
12	H. 13	81	00	27	H. 54	84	00	42	H. 28	88	00
13	H. 45	82	00	28	H. 56	84	00	43	H. 17	88	30
14	H. 57	82	00	29	H. 8	84	30	44	H. 19	89	00
15	H. 20	82	30	30	H. 21	85	00				

Variation, 13°. Theoretical mean, 82° 30′. Skulls nearest to mean, H. 20 and H. 46. Average, 83° 25′. Skulls nearest to average, H. 24, H. 40, H. 49.

TABLE XXXV.—*Seriation of 44 German profile angles.—Salado.*

	Angle.	Number of skulls.		Angle.	Number of skulls.
1	76° to 77°	1	8	83°	3
2	77	2	9	84	10
3	78	2	10	85	4
4	79	2	11	86	5
5	80	4	12	87	2
6	81	1	13	88	3
7	82	4	14	89 to 90	1

Maximum of frequency, 84°.

TABLE XXXVI.—*Ordination of 39 gnathic indices.—Salado.*

	No. of skull.	Index.		No. of skull.	Index.		No. of skull.	Index.
1	H. 18	88.78	14	H. 24	93.68	27	H. 7	97.00
2	H. 19	89.90	15	H. 13	94.00	28	H. 45	98.01
3	H. 30	90.00	16	H. 28	94.11	29	H. 14	98.01
4	H. 17	90.81	17	H. 29	94.14	30	H. 35	98.36
5	H. 32	91.08	18	H. 23	94.28	31	H. 43	98.94
6	H. 34	91.17	19	H. 25	94.28	32	H. 11	100.00
7	H. 9	91.83	20	H. 40	94.79	33	H. 27	100.51
8	H. 3	92.07	21	H. 6	95.45	34	H. 1	101.04
9	H. 50	92.13	22	H. 8	95.94	35	H. 33	101.05
10	H. 44	93.00	23	H. 10	96.00	36	H. 57	101.12
11	H. 51	93.10	24	H. 5	96.11	37	H. 2	102.06
12	H. 42	93.57	25	H. 15	96.70	38	H. 37	107.36
13	H. 16	93.61	26	H. 41	96.90	39	H. 4	110.11

Variation, 21.33. Theoretical mean, 99.44. Skull nearest mean, H. 11. Average, 95.92.

Skulls H. 7, H. 15, H. 18, H. 19, H. 23, H. 25, H. 34, H. 40, H. 44, and H. 57 (10 in all) are apparently normal. Their average index is 94.10.

TABLE XXXVII.—*Seriation of 39 gnathic indices.—Salado.*

Index.	Number of skulls.	Index.	Number of skulls.
88 to 89	1	100	2
89	1	101	3
90	2	102	1
91	3	103	0
92	2	104	0
93	5	105	0
94	6	106	0
95	2	107	1
96	4	108	0
97	1	109	0
98	4	110 to 111	1
99	0		

Maximum of frequency, 94.

TABLE XXXVIII.—*Seriation of 37 gnathic indices (aberrant figures excluded).—Salado.*

Index.	Number of skulls.	Index.	Number of skulls.
88 to 89	1	96	4
89	1	97	1
90	2	98	4
91	3	99	0
92	2	100	2
93	5	101	3
94	6	102	1
95	2		

Variation, 13.28. Theoretical mean, 95.42. Skull nearest mean, H. 6. Average, 95.20.

TABLE XXXIX.—*List of indices and angles of alveolo-subnasal prognathism.—Salado.*

No. of skull.	Vertical measurement.	Horizontal measurement.	Index.	Angle.	No. of skull.	Vertical measurement.	Horizontal measurement.	Index.	Angle.
	mm.	*mm.*		°		*mm.*	*mm.*		°
H. 2	15	7.5	50.00	63½	H. 23	15	5	33.33	72
H. 3	19	4	21.05	78	H. 24	16	5	31.25	73
H. 4	15	8	53.33	62	H. 25	22	6	27.27	75
H. 5	21	9	42.85	67	H. 33	21	6	28.57	74½
H. 7	14	6.5	46.42	66	H. 35	20	9	45.00	66
H. 10	20	6.5	32.50	72	H. 37	16	9	56.25	62
H. 11	19	7.5	39.47	68	H. 42	22	7	31.81	72½
H. 14	18	8	44.44	66	H. 43	21	3	14.28	82
H. 15	17	10	58.82	60	H. 45	16	5	31.25	73
H. 16	16	5	31.25	73	H. 46	15	7	46.66	66
H. 17	17	3	17.64	79½	H. 54	17	7	41.17	68
H. 18	20	6	30.00	73	H. 56	16	5	31.25	73
H. 19	17	4	23.52	76	H. 57	13	8	61.53	59½
H. 20	24	8.5	35.41	70½					

TABLE XL.—*Ordination of 27 indices of alveolo-subnasal prognathism.—Salado.*

	No. of skull.	Index.		No. of skull.	Index.		No. of skull.	Index.
1	H. 43	14.28	10	H. 45	31.25	19	H. 14	44.44
2	H. 17	17.64	11	H. 56	31.25	20	H. 35	45.00
3	H. 3	21.05	12	H. 42	31.81	21	H. 7	46.42
4	H. 19	23.52	13	H. 10	32.50	22	H. 46	46.66
5	H. 25	27.27	14	H. 23	33.33	23	H. 2	50.00
6	H. 33	28.57	15	H. 20	35.41	24	H. 4	53.33
7	H. 18	30.00	16	H. 11	39.47	25	H. 37	56.25
8	H. 16	31.25	17	H. 54	41.17	26	H. 15	58.82
9	H. 24	31.25	18	H. 5	42.85	27	H. 57	61.53

Variation, 47.25. Theoretical mean of variation, 37.90. Skull nearest to mean, H. 11. Average, 37.27.

TABLE XLI.—*Ordination of 27 angles of alveolo-subnasal prognathism.—Salado.*

	No. of skull.	Angle.		No. of skull.	Angle.		No. of skull.	Angle.
		°						°
1	H. 57	59½	10	H. 5	67	19	H. 24	73
2	H. 15	60	11	H. 11	68	20	H. 45	73
3	H. 4	62	12	H. 54	68	21	H. 56	73
4	H. 37	62	13	H. 20	70½	22	H. 33	74½
5	H. 2	63½	14	H. 10	72	23	H. 25	75
6	H. 7	66	15	H. 23	72	24	H. 19	76
7	H. 14	66	16	H. 42	72½	25	H. 3	78
8	H. 35	66	17	H. 16	73	26	H. 17	79½
9	H. 46	66	18	H. 18	73	27	H. 43	82

Variation, 22½°. Theoretical mean of variation, 70¾°. Average, 70+°. Skull nearest to mean and average, H. 20

TABLE XLII.—*Seriation of 27 angles of alveolo-subnasal prognathism.—Salado.*

	Angle.	Number of skulls.		Angle.	Number of skulls.
1	59 to 60	1	13	71	0
2	60	1	14	72	3
3	61	0	15	73	5
4	62	2	16	74	1
5	63	1	17	75	1
6	64	0	18	76	1
7	65	0	19	77	0
8	66	4	20	78	1
9	67	1	21	79	1
10	68	2	22	80	0
11	69	0	23	81	0
12	70	1	24	82	1

Maximum of seriation, 73.

TABLE XLIII.—*Ordination of 38 orbital indices.—Salado.*

	No. of skull.	Index.		No. of skull.	Index.		No. of skull.	Index.
1	H. 22	81.81	14	H. 18	89.18	27	H. 41	94.66
2	H. 1	82.92	15	H. 8	89.61	28	H. 32	94.73
3	H. 6	84.61	16	H. 13	89.87	29	H. 37	94.73
4	H. 5	85.36	17	H. 25	90.24	30	H. 20	94.80
5	H. 19	85.71	18	H. 17	90.58	31	H. 11	94.87
6	H. 26	85.71	19	H. 51	90.90	32	H. 12	95.00
7	H. 21	85.89	20	H. 29	91.42	33	H. 27	95.00
8	H. 3	87.17	21	H. 43	91.66	34	H. 40	96.05
9	H. 57	87.83	22	H. 16	91.89	35	H. 4	97.29
10	H. 10	88.09	23	H. 56	92.10	36	H. 15	97.29
11	H. 45	88.15	24	H. 53	92.75	37	H. 14	98.64
12	H. 28	88.57	25	H. 24	93.42	38	H. 36	100.00
13	H. 7	88.75	26	H. 49	94.44			

Variation, 18.19. Theoretical mean of variation, 90.90. Skull nearest to mean, H. 51. Average, 91.10.

Among the above skulls, H. 19, H. 26, H. 21, H. 57, H. 7, H. 18, H. 25, H. 12, H. 40, H. 15, and H. 36, eleven in all, belong to apparently normal skulls; their average index is 91.06.

TABLE XLIV.—*Seriation of 38 orbital indices.—Salado.*

Index.	Number of skulls.	Index.	Number of skulls.
81 to 82	1	91	3
82	1	92	2
83	0	93	1
84	1	94	6
85	4	95	2
86	0	96	1
87	2	97	2
88	4	98	1
89	3	99	0
90	3	100 to 101	1

Maximum of frequency, 94.

TABLE XLV.—*Ordination of 44 nasal indices.—Salado.*

	Number.	Index.		Number.	Index.		Number.	Index.
1	H. 43	44.23	16	H. 24	50.00	31	H. 29	53.57
2	H. 34	44.54	17	H. 2	51.06	32	H. 19	53.84
3	H. 14	45.28	18	H. 8	51.06	33	H. 18	54.00
4	H. 27	45.28	19	H. 32	51.06	34	H. 4	54.34
5	H. 52	45.28	20	H. 40	51.11	35	H. 37	54.73
6	H. 9	45.91	21	H. 42	51.92	36	H. 16	54.94
7	H. 6	46.00	22	H. 5	52.00	37	H. 28	55.55
8	H. 15	46.07	23	H. 35	52.08	38	H. 22	56.52
9	H. 51	47.05	24	H. 45	52.13	39	H. 33	56.66
10	H. 10	47.95	25	H. 3	52.94	40	H. 44	56.86
11	H. 7	48.00	26	H. 17	53.06	41	H. 36	59.34
12	H. 01	48.42	27	H. 26	53.12	42	H. 49	59.37
13	H. 21	48.92	28	H. 41	53.12	43	H. 20	60.00
14	H. 11	48.97	29	H. 56	53.26	44	H. 57	61.11
15	H. 25	49.09	30	H. 50	53.33			

Variation, 16.88. Theoretical mean of variation, 52.67. Skull nearest to mean, H. 3. Average, 51.66.

TABLE XLVI.—*Seriation of 44 nasal indices.—Salado.*

	Index.	Number of skulls.		Index.	Number of skulls.
1	44 to 45	2	10	53	7
2	45	4	11	54	4
3	46	2	12	55	1
4	47	2	13	56	3
5	48	4	14	57	.....
6	49	1	15	58	.....
7	50	1	16	59	2
8	51	5	17	60	1
9	52	4	18	61 to 62	1

Maximum of frequency, 53.

Skull, H. 30, with nose deflected to one side, as by a blow, has an index of 42.34.

TABLE XLVII.—*Anterior nasal spine.—Salado.*

No. of skull.	Descriptive No.	No. of skull.	Descriptive No.	No. of skull.	Descriptive No.
H. 1	2	H. 19	2	H. 36	1
H. 2	2	H. 20	2	H. 37	2
H. 3	3	H. 21	3	H. 42	1
H. 4	3	H. 22	2	H. 43	5
H. 5	2	H. 23	2	H. 44	4
H. 6	1	H. 24	1	H. 45	2
H. 7	3	H. 25	3	H. 46	3
H. 8	1	H. 26	1	H. 48	2
H. 10	3	H. 28	2	H. 49	2
H. 11	1	H. 29	2	H. 50	2
H. 12	2	H. 30	3	H. 54	1
H. 14	3	H. 32	3	H. 56	3
H. 16	2	H. 33	3	H. 57	2
H. 17	2	H. 34	2		
H. 18	1	H. 35	2		

TABLE XLVIII.—*Ordination of 32 palatine indices.—Salado.*

	No. of skull.	Index.		No. of skull.	Index.
1	H. 30	62.74	17	H. 45	73.07
2	H. 27	62.96	18	H. 56	73.07
3	H. 25	63.15	19	H. 17	74.07
4	H. 20	64.86	20	H. 8	74.50
5	H. 1	65.48	21	H. 33	75.47
6	H. 5	66.66	22	H. 49	76.00
7	H. 37	67.67	23	H. 40	76.00
8	H. 35	69.81	24	H. 50	76.19
9	H. 10	70.58	25	H. 57	76.92
10	H. 14	70.58	26	H. 46	77.55
11	H. 43	71.05	27	H. 29	77.90
12	H. 24	71.42	28	H. 28	78.94
13	H. 45	71.69	29	H. 41	80.00
14	H. 14	71.92	30	H. 4	81.63
15	H. 2	73.00	31	H. 16	81.63
16	H. 7	73.07	32	H. 19	84.61

Variation, 21.87. Theoretical mean of variation, 73.67. Skull nearest to mean, H. 17. Average, 72.94.

If the aberrant skull H. 19 were excluded the variation would be 18.89; the mean, 72.18; the skull nearest to mean, H. 14, and the average, 72.57.

TABLE XLIX.—*Seriation of 32 palatine indices.—Salado.*

	Index.	Number of skulls.		Index.	Number of skulls.
1	62 to 63	2	13	74	2
2	63	1	14	75	1
3	64	1	15	76	4
4	65	1	16	77	2
5	66	1	17	78	1
6	67	1	18	79	0
7	68	0	19	80	1
8	69	1	20	81	2
9	70	2	21	82	0
10	71	4	22	83	0
11	72	0	23	84 to 85	1
12	73	4			

Maximum of frequency, 71, 73, and 76.

TABLE L.—*Ordination of palatine depth.—Salado.*

	No. of skull.	Palatine depth.		No. of skull.	Palatine depth.
1	H. 33	21	17	H. 57	15
2	H. 30	20	18	H. 4	14
3	H. 19	19	19	H. 11	14
4	H. 43	19	20	H. 16	14
5	H. 5	18	21	H. 27	14
6	H. 10	18	22	H. 45	14
7	H. 14	18	23	H. 1	13
8	H. 17 (immature)	18	24	H. 2	13
9	H. 20	17	25	H. 7	13
10	H. 24	17	26	H. 26	13
11	H. 41	17	27	H. 8	12
12	H. 31	16	28	H. 29 (child)	11
13	H. 37	16	29	H. 50 (child)	11
14	H. 40	16	30	H. 28 (child)	9
15	H. 49	16	31	H. 51 (child)	8
16	H. 15	15			

TABLE LI.—*Osteometrical measurements and indices of the long bones.—Salado.*

Designation of skeleton.	Humerus.		Radius.		Ulna.		Antibrachial index of right side.	Antibrachial index of left side.	Femur.		Tibia.		Fibula.		Tibio-femoral index of right side.	Tibio-femoral index of left side.
	Right.	Left.	Right.	Left.	Right.	Left.			Right.	Left.	Right.	Left.	Right.	Left.		
H. 1	282	278	216	215	235	237	76.59	77.33	.....	.....	.....	330	c. 321	.....	.....	*78.70
H. 5	302	300	249	247	.....	.....	78.13	79.00	426	431	.....	354	347	341	*83.16	82.13
H. 6	307	304	244	245	263	263	79.47	80.59	c. 424	421	359	.....	337	336	84.66	81.18
H. 7	312	311	246	247	264	c. 265	78.84	79.45	434	437	369	.....	356	360	85.00	*80.07
H. 8	290	279	226	220	249	245	77.93	81.00	399	403	355	.....	326	324	85.02	*86.82
H. 10	.....	.....	230	227	256	254	*79.10	*79.64	.....	.....	.....	.....	.....	.....	.....	.....
H. 14	327	.....	273	267	292	288	84.09	*89.72	.....	.....	.....	.....	.....	397	.....	.....
H. 15	275	277	.....	218	c. 240	235	86.53	78.69	381	390	.....	329	327	326	*92.98	84.35
H. 18	314	308	245	.....	259	.....	78.02	*76.15	428	.....	363	363	355	352	84.81	*86.57
H. 19	323	320	257	253	271	.....	79.56	79.06	332	423	.....	.....	c. 364	364	*82.09	*82.72
H. 21	.....	328	258	.....	271	.....	*85.39	*71.51	.....	c. 456	.....	.....	.....	.....	.....	76.73
H. 25	327	330	269	265	284	.....	82.26	80.30	.....	.....	.....	.....	.....	.....	.....	.....
H. 32	318	317	.....	.....	.....	.....	74.28	*73.99	.....	.....	.....	.....	375	.....	.....	.....
H. 33	275	.....	224	220	.....	.....	81.45	*73.93	393	.....	.....	.....	c. 325	.....	*90.14	.....
H. 36	.....	.....	210	.....	.....	224	*69.50	.....	388	388	331	331	324	.....	85.59	85.30
H. 39	266	264	205	202	.....	218	77.06	76.51	370	372	303	.....	292	292	81.89	94.06
H. 41	298	294	.....	.....	.....	.....	*79.27	*79.78	410	.....	355	.....	349	345	86.58	.....
H. 45	309	307	235	.....	.....	.....	76.05	*76.40	.....	.....	.....	.....	.....	.....	.....	.....
H. 48	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	403	.....	.....	.....	*97.04	.....
H. 57	.....	270	.....	.....	.....	235	.....	86.87	374	376	321	323	315	319	85.82	85.90
H. 59	284	280	.....	225	.....	243	*83.17	80.25	400	401	.....	343	328	330	*86.57	85.53
H. 60	.....	298	231	228	.....	.....	76.45	76.51	410	415	350	350	.....	.....	85.36	84.33
H. 61	.....	.....	.....	.....	260	257	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H. 63	332	.....	.....	.....	.....	268	71.15	.....	.....	.....	.....	.....	.....	.....	.....	.....
H. 64	310	307	.....	.....	.....	.....	*76.20	*76.40	.....	.....	.....	.....	.....	.....	.....	.....
H. 67	.....	.....	.....	.....	230	227	.....	.....	.....	.....	.....	.....	.....	307	.....	.....
H. 68	278	274	c. 207	203	.....	212	74.46	74.90	.....	.....	.....	.....	.....	c. 309	.....	.....
H. 70	280	278	214	214	.....	.....	76.42	*76.97	384	389	323	326	.....	313	84.11	83.80
H. 71	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	355	.....	.....	.....
H. 72	.....	328	263	262	.....	278	*87.05	79.87	463	464	.....	402	391	387	*76.51	86.63
H. 77	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	c. 386	.....	.....	.....	*92.94	.....
H. 79	.....	.....	.....	251	.....	.....	.....	*84.34	430	433	368	c. 364	.....	362	80.55	84.06
H. 84	.....	.....	.....	.....	247	.....	.....	.....	.....	.....	.....	c. 339	.....	.....	.....	*80.84
H. 85	.....	.....	.....	.....	.....	.....	.....	.....	423	.....	.....	.....	353	.....	*83.75	.....
H. 86	333	.....	.....	.....	284	.....	*70.93	.....	449	451	394	395	.....	.....	87.75	87.58
H. 87	322	.....	.....	.....	.....	.....	*73.36	.....	.....	435	.....	.....	.....	.....	.....	*80.44
H. 88	.....	.....	.....	.....	272	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H. 91	.....	.....	.....	.....	.....	.....	.....	.....	479	480	.....	.....	.....	400	*73.96	*72.90
H. 92	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	354	.....	.....	.....
H. 93	298	.....	.....	.....	.....	.....	*79.27	.....	.....	.....	.....	.....	.....	.....	.....	.....
Miscellaneous: Set I	.....	.....	.....	.....	.....	.....	.....	.....	c. 424	430	.....	.....	.....	.....	*83.55	*81.27
Set II	.....	.....	.....	.....	.....	.....	.....	.....	.....	c. 391	.....	.....	.....	.....	.....	*89.49
Set III	.....	.....	.....	.....	.....	240	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Humerus	277	.....	.....	.....	.....	.....	*85.28	.....	.....	.....	.....	.....	.....	.....	.....	.....
Humerus	316	.....	.....	.....	.....	.....	*74.73	.....	.....	.....	.....	.....	.....	.....	.....	.....
Radius	.....	.....	249	.....	.....	.....	*82.41	.....	.....	.....	.....	.....	.....	.....	.....	.....
Radius	.....	.....	211	.....	.....	.....	*66.52	.....	.....	.....	.....	.....	.....	.....	.....	.....
Radius	.....	.....	.....	242	.....	.....	.....	*81.32	.....	.....	.....	.....	.....	.....	.....	.....
Fibula	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	380	.....	.....
Average	302.12	297.57	246.23	234.57	261.06	246.41	78.18	78.86	415.28	419.30	354.28	349.92	341.78	344.85	85.28	83.54

NOTE.—All the indices thus (*) marked were obtained by using in the calculation the average length of the respective series in place of the length of the missing bone.

TABLE LII.—*Synopsis of average indices of the long bones.—Salado.*

	Antibrachial.						Tibio-femoral.					
	Of right arm.		Of left arm.		Of total or both arms.		Of right leg.		Of left leg.		Of total of both legs.	
	Number of individual indices.	Average.	Number of individual indices.	Average.	Number of individual indices.	Average.	Number of individual indices.	Average.	Number of individual indices.	Average.	Number of individual indices.	Average.
Computed by method I	14	78.66	14	78.60	14	78.63	12	84.73	10	84.96	11	84.83
Computed by method II	18	77.81	12	79.17	15	78.35	11	85.87	13	82.45	12	84.02
Total	32	78.18	26	78.86	29	78.49	23	85.28	23	83.54	23	84.41

TABLE LIII.—*Antibrachial and tibio-femoral indices in various races.*

	Antibrachial index.		Tibio-femoral index.
111 Europeans	72.47	9 Esthonians	78.60
9 Esthonians	73.10	6 Tartars	79.60
6 Egyptians	74.60	72 Europeans	81.02
6 Tartars	74.70	6 Chinese and Javanese	81.03
7 Arabs and Berbers	74.85	5 Polynesians	82.20
5 Koorgans in Russia	75.40	7 Arabs and Berbers	82.61
11 South Americans	75.77	42 African Negroes	83.26
11 New Caledonians	75.94	11 New Caledonians	83.48
7 Hindoos	76.25	11 South Americans	83.55
7 Chinese, Annamites, and Javanese	77.97	23 Saladoans	84.11
29 Saladoans	78.49		
42 African Negroes	78.83		

NOTE.—The number 29, referring to the Saladoans, means 29 indices of various individuals, not the indices of 29 individuals.

NOTE.—The number 23, referring to the Saladoans, means 23 indices of various individuals, not the indices of 23 individuals.

All the figures in the above table, except those concerning Saladoans, are from Topinard.* We have not copied all his figures, however, but only those which deal with five or more individuals. To make his data more comparable with ours we have combined the indices of the two sexes which he gives separately.

TABLE LIV.—*Dimensions and indices of 11 Scapulæ.—Salado*

Designation of skeletons.	Length.		Width.		Indices.	
	Right scapulæ.	Left scapulæ.	Right scapulæ.	Left scapulæ.	Right scapulæ.	Left scapulæ.
H. 1	135ca	.....	93	.....	68.88	.....
H. 6	142	147	99	101	69.71	68.70
H. 8	136	137	97	101	71.32	73.72
H. 21	.....	152	.....	102	.....	67.10
H. 25	161	160	105	110	65.21	68.75
H. 33	130	.....	94	.....	72.30	.....
H. 36	120	.....	98	.....	81.66	.....
H. 45	.....	138	.....	103ca	.....	71.63
H. 68	132	130	90	92	68.18	70.76
H. 70	123	.....	97	.....	78.86	.....
H. 72	102	.....	108	.....	66.66	.....
Average index					71.42	70.61

General average index, 71.09.

TABLE LV.—*Angle of torsion of humerus.—Ordination according to right humerus.—Salado*

	No.	Sex.	Right.	Left.		No.	Sex.	Right.	Left.
			° ′					° ′	
1	.....	.....	146 00	148 30	12	.....	.....	160 00	.....
2	.....	.....	148 00	155 00	13	H. 15	F.	160 30	154 00
3	H. 26	M.	148 30	.....	14	.....	M.	161 00	.....
4	H. 5	F.	151 30	151 00	15	H. 41(?)	M.	161 30	153 00
5	.....	.....	153 30	166 00	16	H. 8	F.	161 30	162 30
6	.....	F.	155 00	157 30	17	H. 25	M.	166 00	166 00
7	H. 33	.....	155 00	.....	18	H. 6	M.	170 00	168 30
8	H. 39	F.	157 00	169 00	19	H. 33	.....	174 00	.....
9	H. 19	M.	158 30	150 00	20	H. 45	.....	174 00	169 00
10	H. 1	F.	158 30	152 00	21	.....	.....	177 00	.....
11	H. 32	M.	158 30	161 30					

Average of 21 right humeri = 159° 45′.
Average of 41 humeri, both sides = 159° 30′+.

* TOPINARD: *Op. cit.*, pp. 1043, 1015.

TABLE LVI.—*Angle of torsion of humerus.—Ordination according to left humerus.—Salado.*

	Number.	Sex.	Left.		Right.			Number.	Sex.	Left.		Right.	
			°	′	°	′				°	′	°	′
1	.....	.....	148	30	146	00	11	H. 32	M.	161	30	158	30
2	H. 19	M.	150	00	158	30	12	.....	.....	161	30	.....	
3	H. 5	F.	151	00	151	30	13	H. 8	F.	162	30	161	30
4	H. 1	F.	152	00	158	30	14	.....	.....	164	00	.....	
5	H. 7	M.	152	30	.....		15	.....	.....	166	00	153	30
6	H. 41(?)	.....	153	00	161	30	16	H. 25	M.	166	00	166	00
7	H. 15	F.	154	00	160	30	17	H. 6	M.	168	30	170	00
8	.....	.....	155	00	148	00	18	H. 39	F.	169	00	157	00
9	H. 57	.....	157	00	.....		19	H. 45	.....	169	00	174	00
10	.....	F.	157	30	155	00	20	.....	.....	172	00	.....	

Average of 20 left humeri=159° 30′.

TABLE LVII.—*Mean angles of torsion of pairs of humeri.—Salado.*

	Designation.	Sex.	Mean angle of pair.			Variation between right and left humerus.		
			°	′		°	′	
1	.....	.....	147	15		2	30	
2	H. 5	F.	151	15			30	
3	.....	.....	151	30		7	00	
4	H. 19	M.	154	15		8	30	
5	H. 1	F.	155	15		6	30	
6	.....	F.	156	15		1	30	
7	H. 41(?)	.....	157	15		8	30	
8	H. 15	F.	157	15		6	30	
9	.....	.....	159	45		12	30	
10	H. 32	M.	160	00		3	00	
11	H. 8	F.	162	00		1	00	
12	H. 39	F.	163	00		12	00	
13	H. 25	M.	166	00		.....		
14	H. 6	M.	169	15		1	30	
15	H. 45	.....	171	30		5	00	

Average mean angle of 15 pairs=158° 47′.
Average variation between right and left humerus, 5° 6′.

TABLE LVIII.—*Torsion of the humerus with regard to sex.—Salado.*

Male.						Female.					
Designation of skeleton.	Right humeri.		Left humeri.			Designation of skeleton.	Right humeri.		Left humeri.		
	°	′	°	′			°	′	°	′	
H. 19	158	30	150	00		H. 5	151	30	151	00	
H. 32	158	30	161	30		.....	155	00	157	30	
H. 25	166	00	166	00		H. 39	157	00	169	00	
H. 6	170	00	168	30		H. 1	158	30	152	00	
						H. 15	160	30	154	00	
						H. 8	161	30	162	30	
Average...	163	15	161	30		Aervage...	157	20	157	30	

Total average of males, 162° 22′.
Total average of females, 157° 30′.

TABLE LIX.—*Torsion of the humerus in specimens in the general collection of the Army Medical Museum.*

	Museum No.	Race or nation.	Sex.	Left.	Right.
				°	
1	165	Mound Builder	M.	150.00	152.50
2	2621	do		148.00	152.00
3	1530	Apache	M.	154.25	135.50
4	1790	Sioux, Sisseton	F.	158.50	154.25
5	1791	do	M.	162.75	155.25
6	1792	do	M.	156.75	154.25
7	1852	Sioux, Brulé	M.	141.00	141.00
8	1896	do	M.	156.00	148.75
9	1897	do	F.	155.00	156.75
10	1898	do	M.	160.25	151.00
11	1901	do	M.	150.50	136.75
12	2062	do	M.	154.75	151.50
13	2068	do	F.	151.00	152.75
14	1853	Sioux, Ogahalla	F.	142.25	151.50
15	1854	do	F.	150.50	144.00
16	2046	Sioux	F.	156.50	156.75
17	2074	do	M.	157.00	157.50
18	2072	do	F.	157.00	158.50
19	2036	Cheyenne	M.	153.25	159.25
20	2066	do	M.	154.50	142.75
21	6499	Arapahoe	M.	168.25	162.75
22	1595	Peruvian	F.	161.75	162.00
23	1	French	M.	174.00	179.00
24	121	do	F.	169.75	166.75
25	1578	do	M.	170.00	159.50
26	1584	do	M.	178.50	175.25
27	1585	do	F.	175.50	172.50
28	1620	do	M.	176.00	176.25
29	2435	do	F.	170.25	160.00
30	2372	Lapp	F.	161.75	160.25
31	2373	do		173.75	164.25
32	2374	do		167.00	161.50
33	2375	do		165.50	161.75
34	2376	do		165.75	166.50
35	2377	Finn		158.50	153.00
36	956	Chinese	M.	159.50	156.00
37	1835	Mulatto	M.	157.00	151.00
38	2040	do	F.	161.00	165.00
39	552	Negro	F.	157.00	140.50
40	1021	do	F.	150.25	153.00
41	2037	do	F.	160.00	158.50
42	2041	do	M.	169.75	161.25
43	2103	do	M.	148.50	150.50
		Average angle of American Indians		154.67	151.96
		Average angle of all others		165.20	161.86
		Average angle of total		159.81	156.63

TABLE LX.—*Torsion of the humerus in specimens in the general collection of the Army Medical Museum (series less than five excluded).—Average for male and female and for right and left.*

Race or nation.	Number of individuals.	Female.			Male.			Undetermined sex.			Right total.	Left total.	Total of all.
		Right.	Left.	Total.	Right.	Left.	Total.	Right.	Left.	Total.			
French	3 females. 4 males.	166.41	171.83	169.12	172.50	174.62	173.56				169.89	173.42	171.66
Lapps	1 female. 4 undetermined.	160.25	161.75	161.00				163.50	168.00	165.75	162.85	166.75	164.80
Sioux or Dakotas	7 females. 8 males.	153.50	152.96	153.25	150.25	155.25	152.75				151.76	154.18	152.97
Other North Americans	5 males. 1 undetermined.				150.55	156.05	153.30	152.00	148.00	150.00	150.70	154.70	152.75
Negroes	3 females. 2 males.	150.66	155.75	153.20	155.87	159.12	157.50				152.75	157.10	154.92

TABLE LXI.—*Indices of 19 pelves—Salado.*

Designation of skeleton.	Breadth-height index.	Superior strait index.	Pubo-ischiatic depth index	Sacral length index.
H. 1	.....	77.95	65.35	72.44
H. 5	135.32	84.72	66.66	77.08
H. 6	136.36	91.45	76.06	94.87
H. 7	145.83	74.04	71.75	67.93
H. 8	142.32	85.82	66.14	80.31
H. 10	148.92	80.41	66.43	65.03
H. 14	131.77	103.44	77.58	83.62
H. 15	152.09	74.61	59.23	73.84
H. 18	.....	86.03	68.99	.....
H. 19	.....	89.65	81.89	95.68
H. 25	140.60	82.81	81.25	.....
H. 36	149.42	76.92	70.76	76.92
H. 39	152.38	69.04	66.66	.....
H. 41	131.18	78.63	80.34	86.32
H. 45	.....	82.26	63.12	73.75
H. 57	152.66	82.53	64.28	76.98
H. 59	137.07	69.06	62.58	66.18
H. 72	146.96	80.14	69.85	82.35
H. 96	130.17	78.21	75.24	89.10

TABLE LXII.—*Ordination of breadth-height indices of 14 pelves—Salado.*

	Designation of skeleton.	Index.	Sex.		Designation of skeleton.	Index.	Sex.
1	H. 41	131.18	Male.	8	H. 7	145.83	Male.
2	H. 14	131.77	Male.	9	H. 72	146.96	Male.
3	H. 5	135.32	Female.	10	H. 10	148.92	Female.
4	H. 6	136.36	Male.	11	H. 36	149.42	Female.
5	H. 59	137.07	Female.	12	H. 15	152.09	Female.
6	H. 25	140.60	Male.	13	H. 39	152.38	Female.
7	H. 8	142.32	Female.	14	H. 57	152.66	Female.

TABLE LXIII.—*Ordination of superior strait indices of 18 pelves.—Salado.*

	Designation of skeleton.	Index.	Sex.		Designation of skeleton.	Index.	Sex.
1	H. 39	69.04	Female.	10	H. 45	82.26	Female.
2	H. 59	69.06	Female.	11	H. 57	82.53	Female.
3	H. 7	74.04	Male.	12	H. 25	82.81	Male.
4	H. 15	74.61	Female.	13	H. 5	84.72	Female.
5	H. 36	76.92	Female.	14	H. 8	85.82	Female.
6	H. 1	77.95	Female.	15	H. 18	86.03	Male.
7	H. 41	78.63	Male.	16	H. 19	89.65	Male.
8	H. 72	80.14	Male.	17	H. 6	91.45	Male.
9	H. 10	80.41	Female.	18	H. 14	103.44	Male.

TABLE LXIV.—*Ordination of 18 pubo-ischiatic indices.—Salado.*

	Designation of skeleton.	Index.	Sex.		Designation of skeleton.	Index.	Sex.
1	H. 15	59.23	Female.	10	H. 18	68.99	Male.
2	H. 59	62.58	Female.	11	H. 72	69.85	Male.
3	H. 15	63.12	Female.	12	H. 36	70.76	Female.
4	H. 57	64.28	Female.	13	H. 7	71.75	Male.
5	H. 1	65.35	Female.	14	H. 6	76.06	Male.
6	H. 8	66.14	Female.	15	H. 14	77.58	Male.
7	H. 10	66.13	Female.	16	H. 41	80.34	Male.
8	H. 5	66.66	Female.	17	H. 25	81.25	Male.
9	H. 39	66.66	Female.	18	H. 19	81.89	Male.

TABLE LXV.—*Ordination of 15 sacral length indices.—Salado.*

	Designation of skeleton.	Index.	Sex.		Designation of skeleton.	Index.	Sex.
1	H. 10	65.03	Female.	9	H. 5	77.08	Female.
2	H. 59	66.18	Female.	10	H. 8	80.31	Female.
3	H. 7	67.93	Male.	11	H. 72	82.35	Male.
4	H. 1	72.44	Female.	12	H. 11	83.62	Male.
5	H. 45	73.75	Female.	13	H. 41	86.32	Male.
6	H. 15	73.84	Female.	14	H. 6	94.87	Male.
7	H. 36	76.92	Female.	15	H. 19	95.68	Male.
8	H. 57	76.98	Female.				

TABLE LXVI.—*Breadth-height indices (general index of the pelvis) in various races.*

Males.		Females.	
6 Saladoans	138.78	8 Saladoans	146.27
46 Europeans	126.60	21 Europeans	136.90
17 African negroes	121.30	10 African negroes	134.20
11 Oceanian negroes	122.70	10 Oceanian negroes	129.00

NOTE.—With the exception of the Saladoan these data are from TOPINARD's Éléments d'anthropologie, p. 1049.

TABLE LXVII.—*Indices of the superior strait in various races.*

Males.		Females.	
63 Europeans	80.00	10 Saladoans	78.33
2 Lapps	83.00	49 Europeans	79.00
8 Saladoans	85.77	6 African negresses	81.00
1 Tasmanian	88.00	3 Peruvians	83.00
17 African negroes	89.00	7 Australians	88.00
12 New Caledonians	91.00	3 New Caledonians	89.00
1 Australian	98.00	1 Javanese	90.00
		13 Andamanese	99.00

NOTE.—With the exception of the figures on the Saladoans, these data are from TOPINARD's Éléments d'anthropologie, p. 1050.

TABLE LXVIII.—*19 different measurements of 30 pelves.—Salado.*

Designation of skeletons.	Conjugata externa.	Crest width.	Antero-superior spinal width.	Posterior-superior spinal width.	Antero-posterior diameter of brim.	Transverse diameter of brim.	Antero-posterior diameter of outlet.	Transverse diameter of outlet.	Sciatic width.	Pelvic height.	
										Right.	Left.
H. 1	161	.....	.....	.....	99	127	124	100	91 ca.	170	.....
H. 5	188	272	233	103	122	144 ca.	118	120	114	201	202
H. 6	163	255	220	72	107	117	101 ca.	87	78	187	190
H. 7	155	280	249	.....	97 ca.	131	118	93	86	192	193
H. 8	161	269	234	77	109	127	113	110	99	189	181
H. 10	187 ca.	277	244	92 ca.	115	143	150	112	102	186	188
H. 14	174 ca.	253	205	.....	120	116	108	92	82 ca.	192	188
H. 15	154	245	211	77	97	130	119	123	.....	167	168
H. 18	165 ca.	.....	224	.....	111 ca.	129	.....	100 ca.	87 ca.	192	.....
H. 19	.....	.....	.....	.....	104	116	88	77	.....	.....	202
H. 21	.....	.....	.....	.....	.....	.....	.....	.....	.....	209	206
H. 25	158 ca.	277	241 ca.	.....	106	128	.....	.....	.....	.....	197
H. 27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H. 33	.....	.....	.....	.....	.....	.....	.....	.....	.....	176	.....
H. 35	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H. 36	158	260	229	88	100	130	108 ca.	107	.....	174	173
H. 39	.....	256	245	.....	87	126	.....	103	.....	168	.....
H. 41	149	244 ca.	.....	86	92	117	97	90	.....	186	186
H. 45	165	.....	.....	92	116	141	117	125	114	.....	195
H. 57	159	258	234	.....	104	126	114	106	101	.....	169
H. 59	169	244	227	85	96	139	119	109	108	178	179
H. 61	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H. 63	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H. 72	154 ca.	291	263	.....	109	136	105	107	99 ca.	.....	198
H. 79	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H. 84	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
H. 87	.....	.....	.....	.....	.....	.....	.....	.....	.....	187	.....
H. 96 (child, epiphyses absent)	130	220	201	72 c.	79	101	94	69	.....	169	169
B.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
C.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

Designation of skeletons.	Iliac breadth.		Height of iliac fossa.		Cord of the brim.	Pubo-ischiatic depth.		Acetabulo-symphysial width.	Sacral length.	Sacral breadth.	Width of sacrum at brim.	Inferior width of sacrum.
	Right.	Left.	Right.	Left.		Right.	Left.					
H. 1	.....	.....	.....	.....	106	.....	83 ca.	113	92	101	92	83
H. 5	.....	152	89	.....	131	96	96	128	111	126	107	101
H. 6	149	.....	89	90	107 ca.	89	91	110	111	116	100	83
H. 7	153	.....	89	89	106	94	95	118	89	117	110	91
H. 8	141	144	83	83	108	84	84	114	102	122	105	81
H. 10	154	.....	88	90	127	95	95	131	93 (5 v)	126	109	96
H. 14	.....	.....	92	87	118	90	90	119	97	120	98	.....
H. 15	139	140	85	80	105	77 ca.	76	112	96	103	101	83
H. 18	.....	121 ca.	82	.....	112	89	.....	129	.....	110	106	87
H. 19	.....	.....	.....	.....	108	.....	95	115	111	122	99	90
H. 21	.....	.....	98 ca.	96 ca.	115	98	100	122	.....	.....	.....	.....
H. 25	160 ca.	.....	.....	96	112 ca.	.....	104	129	.....	.....	104	.....
H. 27	.....	.....	.....	.....	.....	.....	.....	.....	112	118	100	92
H. 33	.....	.....	82	.....	113	88	.....	108	93 (5 v)	111	99	86
H. 35	.....	.....	.....	.....	.....	.....	.....	.....	103	113	109	90
H. 36	133	131 ca.	82	79	114	92	90	120	100 (5 v)	117	105	86
H. 39	133	.....	82 ca.	.....	105	84	84	112	.....	106	101	.....
H. 41	132	.....	88	89 ca.	100	94	89 ca	105	101	108	99	74
H. 45	152 ca.	149	.....	95	106	.....	89	119	104	122	109	95
H. 57	.....	.....	85	83	105	81	82	112	97	113	104	82
H. 59	134	136	81	83	121	87	87	114	92	111	104	91
H. 61	.....	.....	.....	.....	.....	.....	.....	.....	105	.....	.....	93
H. 63	.....	.....	.....	.....	.....	.....	.....	.....	102 (5 v)	117 ca.	110	92 ca.
H. 72	.....	163	.....	99	111	95	.....	120	112	129	115	96
H. 79	.....	.....	.....	.....	.....	.....	.....	.....	108 ca.	106	94	80 ca.
H. 84	.....	.....	.....	.....	.....	.....	.....	.....	96	121	115	90
H. 87	144	.....	87	.....	.....	.....	.....	.....	105	117 ca.	98	88
H. 96 (child, epiphyses absent)	115	116	72	74	91	76	76	99 ca.	90	92	88	70
B.	.....	.....	.....	.....	.....	.....	.....	.....	97	121	99	89
C.	.....	.....	.....	.....	.....	.....	.....	.....	92	111	104	90

TABLE LXIX.—*Pilaster femur—Indices of transverse section of shaft of femur from 54 skeletons, more or less complete.—Salado.*

Designation of skeleton	Right, 49.			Left, 47.			Remarks.
	Antero-posterior diameter.	Lateral diameter.	Index.	Antero-posterior diameter.	Lateral diameter.	Index.	
H. 1	23½	23	102.17	23½	23½	100.00	Both diameters a little oblique.
H. 2	30	23	130.43	.....	.....	.....	
H. 5	30¼	23	132.60	30	24	125.00	
H. 6	30	21½	139.53	31	24	147.61	
H. 7	32	24	133.33	30	23½	127.65	
H. 8	27½	23	119.56	29	24	120.83	
H. 9	24	24½	97.95	23½	24	97.91	
H. 10	27½	26½	103.77	28	25½	109.80	
H. 15	24	21½	111.62	23½	21½	109.30	
H. 19	30	21½	122.44	31	25	124.00	Slight exostosis in left.
H. 21	32	27½	116.36	33	27	122.22	
H. 25	32	23	139.13	31½	24	131.25	
H. 29	17	13	130.76	16½	13	126.92	Young child.
H. 30	29	25	116.00	31	23	134.78	Femora bowed forward.
H. 32	28	24	116.66	27½	23	119.56	
H. 33	.....	.....	.....	24	21	114.28	
H. 34	30	23½	127.65	30	25	120.00	
H. 36	27	23	117.39	26½	23	115.21	
H. 39	23	22	104.54	23	21	109.52	
H. 41	25½	22½	113.33	25½	24	106.25	
H. 42	33	24½	134.69	32	25	128.00	Exostotic fringes on linea aspera.
H. 45	26	22½	115.55	26½	22½	117.77	
H. 57	25	22	113.63	25	22	113.63	
H. 58	.....	.....	.....	29	25½	113.72	
H. 59	24	21½	111.62	24	20½	117.07	
H. 60	25	22	113.63	25	21	119.04	
H. 62	30	27	111.11	.....	.....	.....	
H. 63	31	25	124.00	31	24½	126.53	Slight exostosis on right.
H. 64	27	29	93.10	.....	.....	.....	
H. 65	29	25	116.00	.....	.....	.....	
H. 66	24½	23½	101.25	.....	.....	.....	
H. 67	25	25	100.00	.....	.....	.....	
H. 69	16½	14	117.85	16	14	114.28	Child.
H. 70	24½	23	106.52	25½	23½	108.51	
H. 71	.....	.....	.....	27	21	128.57	
H. 72	30½	23½	129.78	30	24	125.00	
H. 73	30½	24	127.08	29	23½	123.40	
H. 74	24	24½	97.95	24½	24½	100.00	
H. 75	26	24	108.33	26	25	104.00	
H. 76	24	22	109.09	24	22	109.09	
H. 77	25½	23	110.86	26½	23	115.21	
H. 78	27	24½	110.20	.....	.....	.....	
H. 79	28½	26½	107.54	29	25½	113.72	
H. 81	.....	.....	.....	25½	24	106.25	
H. 82	24	23	104.34	25	22½	111.11	
H. 85	25½	23½	108.51	26½	25	106.00	
H. 86	33	24½	134.69	30½	26½	115.09	
H. 87	30½	23	132.60	30	23	130.43	
H. 88	.....	.....	.....	29½	23	128.26	
H. 90	28	25	112.00	30	23½	127.65	
H. 91	29	27	107.40	29	27	107.40	
H. 92	28	23	121.73	27	24½	110.20	
H. 93	26	22½	115.55	25½	23	110.86	
H. 96	19	19½	97.43	23	18½	124.32	Youth.
Average index	.....	.....	115.76	.....	.....	117.38	

Average index of total, 116.45.

TABLE LXX.—*Pilaster femur—Indices of transverse section of shaft of femur, miscellaneous.—Salado.*

Designation of skeleton.	Right, 17.			Left, 18.			Remarks.
	Antero-posterior dimension.	Lateral dimension.	Index.	Antero-posterior dimension.	Lateral dimension.	Index.	
S I	27	24	112.50	28	23	121.73	
S II	25½	25½	100.00	25	24½	102.04	
A	29½	20½	143.90	28	21	133.33	
B	25	22½	111.11	24	23	104.34	
C	27	27	100.00	27	26	103.84	
D	17½	16½	106.06	18½	16	115.62	Child.
E	.....	.....	.....	28	22	127.27	
F	26	23	113.04	25½	23	110.86	
G	25	23	108.69	26	22½	115.55	
H	26	23	113.04	.....	.....	.....	
I	31	27	114.81	31	28½	108.77	
K	26	24½	106.12	.....	.....	.....	
L	.....	.....	.....	33	25½	129.41	
M	25½	22	115.90	.....	.....	.....	
N	27	25	108.00	.....	.....	.....	
O	.....	.....	.....	29½	25½	115.68	
P	.....	.....	.....	27	24	112.50	
Q	.....	.....	.....	25	20	120.00	
R	26½	23½	112.76	.....	.....	.....	
S	.....	.....	.....	25	23	108.69	
T	.....	.....	.....	25½	22½	111.11	
U	.....	.....	.....	24	20	120.00	Both diameters a little oblique.
V	32	25½	125.45	.....	.....	.....	
W	25	24	104.16	.....	.....	.....	
X	.....	.....	.....	21	17	123.52	Child.
Y	20½	19½	105.12	.....	.....	.....	
Average index.....			111.80	.....		115.79	

Average index of total, 113.85.

TABLE LXXI.—*Indices of section of the femur in 16 Peruvian skeletons in Army Medical Museum.*

Specimens of provisional section, A. M. M.	Number of specimen.	Right.			Left.			Remarks.
		Antero-posterior dimension.	Lateral dimension.	Index.	Antero-posterior dimension.	Lateral dimension.	Index.	
	1595	23	22½	102.22	23½	24	97.91	Female.
	2555	30	27½	110.90	.....	.....	.....	
	3131	22	20	110.00	22½	22	102.27	Adolescent.
	3132	27	29½	91.52	25½	29½	86.44	
	446	24	22½	106.66	24½	23	106.52	
	447	31½	24½	128.57	32	25	128.00	
	448	25½	26	98.07	29	27	107.40	
	449	27	24½	110.20	26½	23½	112.76	
	450	30	29	103.44	32	27	118.51	
	451	27½	25	110.00	27½	25	110.00	
	452	27½	28½	96.49	28	28½	98.24	
	453	24	22	109.09	23½	23½	100.00	
	454	25	25½	98.03	25½	25½	100.00	
	455	31	26	119.23	30½	26	117.30	
	456	.....	.....	.....	31½	29	108.62	
	457	.....	.....	.....	33	30	110.00	
	Average index			106.74	.....		106.93	

Average index of total, 106.84.

TABLE LXXII.—*Of indices of transverse section of shaft of femur—entire collection of Salado.*

Average of 66 femora of right side	114.74
Average of 65 femora of left side	116.94
Average of 131 femora of both sides	115.83
Maximum (H. 6, left)	147.61
Minimum (H. 64, right)	93.10

TABLE LXXIII.—*Relations existing between pilaster femur and platycnemic tibia.—Salado.*

[The first 5 skeletons have the lowest average tibial index and the highest average femoral index. In the last 5 the conditions are reversed.]

	Designation of skeleton.	Tibiæ.			Femora.		
		Right.	Left.	Both.	Right.	Left.	Both.
Lowest	H. 6	51.42	49.29	50.35	139.53	147.61	143.57
	H. 19	48.75	48.75	48.75	122.44	124.00	123.22
	H. 21	59.15	50.60	54.87	116.36	122.22	119.29
	H. 30	54.54	51.47	53.00	116.00	134.78	125.39
	H. 87	52.11	50.00	51.05	132.60	130.43	131.51
Total average		53.19	50.02	51.60	125.38	131.80	128.59
Highest	H. 5	73.33	70.49	71.91	132.60	125.00	128.80
	H. 36	76.28	75.43	75.85	117.39	115.21	116.30
	H. 63	62.16	68.57	65.36	124.00	126.53	125.26
	H. 70	69.49	68.75	69.12	106.52	108.51	107.51
	H. 74	74.19	79.03	76.61	97.95	100.00	98.97
Total average		71.09	72.45	71.77	115.69	115.05	115.37

TABLE LXXIV.—*Platycnemia.—Indices of transverse section of shaft in 90 tibiæ from 52 skeletons more or less complete.—Salado.*

Designation of skeleton.	Right side.			Left side.			Remarks.
	Antero-posterior dimension.	Lateral dimension.	Index.	Antero-posterior dimension.	Lateral dimension.	Index.	
H. 1	26½	16	60.37	27	17	62.96	
H. 2	.....	.....	.....	33	21	63.63	
H. 5	30	22	73.33	30½	21½	70.49	
H. 6	35	18	51.42	35½	17½	49.29	
H. 7	36	19	52.77	35	20	57.14	
H. 9	29	18½	63.79	30½	20½	67.21	
H. 10	34	20	58.82	34	22	64.70	
H. 14	30	20	66.66	32	20	62.50	
H. 15	27	17	62.96	26½	16½	62.26	
H. 19	40	19½	48.75	40	19½	48.75	
H. 21	35½	21	59.15	41½	21	50.60	Muscular exostosis.
H. 26	25	19	76.00	28	20	71.42	Youth.
H. 29	20	13½	67.50	18½	14	75.67	Child.
H. 30	33	18	54.54	34	17½	51.47	
H. 32	.....	.....	.....	31	21½	69.35	
H. 33	27	17	62.96	.....	.....	.....	
H. 34	35½	23	64.78	34½	23	66.66	
H. 36	28	21½	76.28	28½	21½	75.43	
H. 39	27	15	55.55	26½	15	56.60	
H. 41	32½	21	64.61	32	20	62.50	
H. 42	37	22½	60.81	37½	22	61.97	
H. 45	31½	19½	61.90	31	21	67.74	
H. 48	36	21½	59.72	.....	.....	.....	
H. 57	27	17	62.96	29	18	62.06	
H. 58	32½	23	70.76	33½	24½	73.13	
H. 59	.....	.....	.....	26½	18	67.92	
H. 60	.....	.....	.....	31	19½	62.90	
H. 61	38	22	57.89	.....	.....	.....	
H. 62	36½	21	57.53	.....	.....	.....	
H. 63	37	23	62.16	35	24	68.57	
H. 64	36½	19½	53.42	37	20½	55.40	
H. 65	37	21½	58.10	36	20½	56.94	
H. 67	.....	.....	.....	29	19	65.51	

TABLE LXXIV—Continued.

Designation of skeleton.	Right side.			Left side.			Remarks.
	Antero-posterior dimension.	Lateral dimension.	Index.	Antero-posterior dimension.	Lateral dimension.	Index.	
H. 68	.....	.....	.....	27½	19	69.09	
H. 69	21	15	71.42	19	14½	76.31	Child.
H. 70	29½	20½	69.49	32	22	68.75	
H. 71	30½	20½	67.21	.....	.....	.....	
H. 72	.....	.....	.....	35½	22	61.97	
H. 73	38½	21	54.54	36	20	55.55	
H. 74	31	23	74.19	31	24½	79.03	
H. 77	29	20	68.96	.....	.....	.....	
H. 78	31	20	64.51	33	19	57.57	
H. 79	34	20	58.82	32½	21	64.61	
H. 81	31½	17	53.96	32	17	53.12	
H. 82	25½	17	66.66	25	18½	74.00	Slight exostosis.
H. 84	32½	21	64.61	31	19	61.29	
H. 85	.....	.....	.....	29	20	68.96	
H. 86	38½	20	51.94	37½	19½	52.00	
H. 87	35½	18½	52.11	36	18	50.00	
H. 88	.....	.....	.....	39	22	56.41	
H. 89	29	16½	56.89	.....	.....	.....	
H. 90	33	17½	53.03	.....	.....	.....	Deformed.
.....	34½	24	69.56	37	25½	68.91	
.....	.....	.....	.....	15½	12	77.41	Child.
Average ...	.....	.....	61.78	.....	.....	63.60	

Average of all tibiæ, 62.71. Average of 78 normal adult tibiæ, 61.88.

TABLE LXXV.—*Platycnemia.—Indices of transverse section of shaft in 26 miscellaneous tibiæ.—Salado.*

Designation of skeleton.	Right side.			Left side.			Remarks.
	Antero-posterior dimension.	Lateral dimension.	Index.	Antero-posterior dimension.	Lateral dimension.	Index.	
A	.....	.....	.....	39	26	66.66	
B	.....	.....	.....	27½	19	69.09	
C	.....	.....	.....	34	19	55.88	
D	.....	.....	.....	32	22	68.75	
E	.....	.....	.....	28½	19½	68.42	
F	29	17½	60.34	.....	.....	.....	
G	37½	21	56.00	.....	.....	.....	
H	35	22	62.85	.....	.....	.....	
I	38	21	55.26	.....	.....	.....	
K	.....	.....	.....	29½	21	71.18	
L	.....	.....	.....	30½	17	55 73	
M	36½	22½	61.64	.....	.....	.....	
N and O	40	23	57.50	39	24½	60.28	Pair.
P	.....	.....	.....	27	19	70.37	
Q and R	22½	15	66.66	22	15	68.18	Child.
S and T	21	17	80.95	21	17	80.95	Child.
U	14	12½	89.28	.....	.....	.....	Very young child.
V and W	29	19	65.51	29	19	65.51	Probably a pair.
X	.....	.....	.....	30	19½	65.00	
Y	28	20	71.42	.....	.....	.....	
Z and A^2	28½	20½	71.92	29	20	68.96	Probably a pair.
Average	.....	.....	66.61	.....	.....	66.78	

Average of total, 66.70. Average of 116 tibiæ of both series (regular and miscellaneous), 63.54.

TABLE LXXVI.—*Indices of transverse section of shaft of femur in 62 skeletons of various races in the Army Medical Museum.*

Races.	No. of specimen.	Sex	Right femur.			Left femur.			Remarks.
			Antero-posterior dimension.	Lateral dimension.	Index.	Antero-posterior dimension.	Lateral dimension.	Index.	
White	5433	M.	21	25½	94.11	23½	25½	92.15	Hunchback.
Do	6444	F.	27½	24	111.58	27½	24½	112.24	
Negro	552	F.	23	19½	117.94	24	20½	117.07	15 years of age.
Do	2037	F.	31	25½	121.56	31	25½	121.56	70 years of age.
Do	2041	M.	29½	28	105.35	29½	28	105.35	
Do	2103	M.	28½	27	105.55	29	27	107.40	
Do	3301	F.	25	22	113.63	26	22	118.18	Barely an adult.
Do	5432	F.	38½	24½	159.18	37	25½	145.09	Hunchback.
Mulatto	1835	M.	32½	27½	118.18	33	28½	115.78	
Do	2040	M.	27	23½	114.89	27	23½	114.89	
Mexican	1831	M.	25	21½	116.27	24½	22	111.36	Youth.
Mahlemut Eskimo	756	....	.....	.....	.....	25	26	96.15	Tumor on right femur.
Patagonian	239	F.	26	23½	110.63	25	22½	111.11	
North American Indians.									
Alaskan	814	M.	31½	25½	123.52	30½	26	117.30	
Do	938	M.	31	27½	112.72	31	26½	116.98	Hunchback.
Apache	1173	F.	22½	22½	100.00	22½	23	97.82	
Do	1530	M.	29	25½	113.72	30½	27	112.96	
Arapaho	6490	M.	29	27½	105.45	29½	24½	120.40	
Bannock	2133	M.	31½	26½	118.86	31½	25½	123.52	
Cheyenne	2036	M.	30	27	111.11	30½	27½	110.90	
Do	2066	M.	32½	27½	118.18	31½	27½	114.54	
Do	6966	M.	30	26½	113.20	31½	26½	118.86	Adolescent.
Chippewa	1257	M.	28½	26	109.61	29½	26½	111.32	
Choctaw	622	F.	29	24	120.83	28½	24½	116.32	
Do	623	F.	26½	23½	112.76	29	24	120.83	
Comanche	1000	F.	24	23	104.34	.....	.....	.....	Exostosis of left femur.
Dakota	945	M.	32½	28½	114.03	33	29½	111.86	
Modoc	6287	M.	29½	26	113.46	29	25½	113.72	
Mound-builders:									
From Dakota	165	M.	32	29	110.34	29½	28½	103.50	
Do	1121	M.	32½	27	120.37	.....	.....	.....	
From Mississippi	400	M.	30	32	93.75	28½	33	86.36	
Do	644	M.	29	23	126.08	28½	24	118.75	
Navajo	788	M.	26½	23	115.21	26	24½	106.12	
Pawnee	778	F.	27	23½	114.89	28	25½	109.80	
Pah Utes	963	M.	30½	24½	124.48	30½	25	122.00	
Do	964	F.	24	23½	102.12	23	24	95.83	
Sioux	13	M.	31	28½	108.78	32	26	123.07	
Do	2046	F.	26½	27	98.14	27½	28½	96.49	
Do	2071	M.	33	26½	124.52	32½	26	125.00	
Do	2072	F.	32	26½	120.75	33½	29	115.51	
Brule Sioux	1852	M.	29	26½	109.43	28½	25½	111.76	
Do	1895	M.	31	25½	121.56	31½	26½	118.26	
Do	1896	M.	34½	28½	121.05	35	30½	114.75	
Do	1897	F.	32	26	123.07	32	28	114.30	
Do	1898	M.	32	28½	112.28	32	29	110.34	
Do	1899	M.	36½	28	130.35	36	30½	118.03	
Do	1900	F.	25½	24	106.25	25½	25½	100.00	30 years of age.
Do	1901	M.	33	30½	108.19	33	29	113.79	
Do	2061	M.	31	29	106.89	30	28½	105.26	Adolescent.
Do	2062	M.	34½	27½	125.45	33½	29	115.51	
Do	2063	M.	24½	22	111.36	24½	23	106.52	Adolescent.
Do	2068	F.	28½	27½	103.63	28½	27	105.55	
Ogalalla Sioux	1851	F.?	23	21	109.52	23	22½	102.22	About 15 years of age.
Do	1853	F.	30½	26½	115.09	31	28	110.71	
Do	1854	F.	27	27	100.00	27½	29½	93.22	
Do	1856	M.	24½	21	102.38	21	20½	102.43	About 16 years of age.
Sisseton Sioux	1790	F.	27	27½	98.18	26	26	100.00	
Do	1791	F.	31½	27½	114.54	31	26	119.23	
Do	1792	M.	32	30½	104.91	33	31	106.45	
Yankton Sioux	926	M.	34½	28	123.21	34½	29	118.96	
Asiatics.									
Chinese	956	M.	29½	31½	93.65	30	30	100.00	
Do	957	F.	24	21½	111.62	24	23	104.34	

TABLE LXXVII.—*Platycnemia.—Indices of transverse section of shaft of tibia in 62 skeletons of various races in the Army Medical Museum.*

Races.	No. of specimen.	Sex.	Right tibia.			Left tibia.			Remarks.
			Antero-posterior dimension.	Lateral dimension.	Index.	Antero-posterior dimension.	Lateral dimension.	Index.	
White	5433	M.	28½	23	80.70	29	23	79.31	Hunchback.
Do	6414	F.	30½	23	75.40	28	23	82.14	
Negro	552	F.	27	19	70.37	28	19½	69.64	15 years of age.
Do	2037	F.	30½	22½	73.77	33	22½	68.18	70 years of age.
Do	2041	M.	34	26½	77.94	35	27	77.14	
Do	2103	M.	35	27½	78.57	35½	27½	77.46	
Do	3301	F.	30	22	73.33	31	22	70.96	Barely an adult.
Do	5432	F.	35½	27	76.05	35½	26½	74.64	Hunchback.
Mulatto	1835	M.	35	25	71.42	34½	24	69.56	
Do	2040	M.	31	23	74.19	32	23½	73.43	
Mexican	1834	M.	26	21	80.76	26	21½	82.69	Youth.
Mahlemut Eskimo	756	....	30	20	66.66	29	20½	70.68	
North American Indians.									
Alaskan	814	M.	38½	20½	53.24	.....	.....	.....	
Do	938	M.	34	23	67.64	34½	22½	65.21	Hunchback.
Apache	1473	F.	27	18½	68.51	29½	20	67.79	
Do	1530	M.	34	24	70.58	33	23½	71.21	
Arapaho	6499	M.	37	23	62.16	38½	24½	63.63	
Bannock	2133	M.	33½	28½	85.07	32	30	93.75	
Cheyenne	2036	M.	32½	23	70.76	33½	23	68.65	
Do	2066	M.	41	25	60.97	42	23	54.76	
Do	6966	M.	34½	24½	71.01	35	25	71.42	Adolescent.
Chippewa	1257	M.	33	22	66.66	34	23½	69.11	
Choctaw	622	F.	32½	20	61.53	31½	21½	68.25	
Do	623	F.	31½	21	66.66	30½	21	68.65	
Comanche	1000	F.	28	19	67.85	28	19	67.85	
Dakota	945	M.	40½	27½	67.90	40½	27	66.66	
Modoc	6287	M.	35	23½	67.14	35	22	62.85	
Mound-builders:									
From Dakota	165	M.	38½	24½	63.63	38½	25	64.93	
Do	1121	M.	42	24½	58.33	39½	24½	62.02	
From Mississippi	400	M.	42½	30	70.58	39½	27½	69.62	
Do	644	M.	33	24	72.72	34½	25	72.46	
Navajo	788	M.	33	21½	65.15	34	22½	66.17	Right foramen abnormal; measurement taken on a level to correspond with foramen of opposite side.
Pawnee	778	F.	32	23½	73.43	31½	21½	68.25	
Pah Ute	963	M.	35	21	60.00	35	22	62.85	
Do	964	F.	30	17	56.66	28½	17	59.64	
Sioux	13	M.	36½	24½	67.12	36	25	69.44	
Do	2046	F.	31	24	77.41	31	24	77.41	
Do	2071	M.	34	23½	69.11	35	23½	67.14	
Do	2072	F.	32½	24	73.84	33½	23½	70.14	
Brule Sioux	1852	M.	34	25	73.52	34½	23	66.66	Left foramen abnormal; measurement taken on a level to correspond with foramen of opposite side.
Do	1895	M.	34½	24	69.56	36	23	63.88	
Do	1896	M.	36½	27	73.97	37	29	78.37	
Do	1897	F.	35	27	77.14	36	25½	70.83	
Do	1898	M.	41	28	68.29	41	27	65.85	
Do	1899	M.	43	23	53.48	42½	23½	55.29	
Do	1900	F.	30	21½	71.66	30	21	70.00	30 years of age.
Do	1901	M.	38½	24½	63.63	38	24	63.15	
Do	2061	M.	35½	24½	69.01	35	23½	67.14	Adolescent.
Do	2062	M.	41½	26½	63.85	38½	27½	71.42	
Do	2063	M.	28	21½	76.78	29½	22	74.57	Adolescent.
Do	2068	F.	36	24½	68.05	33	24½	74.24	
Ogalalla Sioux	1851	F.	27	21	77.77	27	20½	75.92	About 15 years of age.
Do	1853	F.	31	20½	66.12	32	20½	64.06	Left foramen abnormal; measurement taken on a level to correspond with foramen on opposite side.
Do	1854	F.	32½	21½	66.15	33	21½	65.15	
Do	1856	M.	26½	19½	73.58	27	20	74.0	About 16 years of age.
Sisseton Sioux	1790	F.	30	22	73.33	30½	22	72.13	
Do	1791	F.	40	23	57.50	38½	24	62.33	
Do	1792	M.	38	28½	75.00	38½	29	75.32	
Yankton Sioux	926	M.	39½	25	63.29	36	25	69.44	

TABLE LXXVII—Continued.

Races.	No. of specimen.	Sex.	Right tibia. Antero-posterior dimension.	Lateral dimension.	Index.	Left tibia. Antero-posterior dimension.	Lateral dimension.	Index.	Remarks.
South American Indians.									
Patagonian	239	F.	30	17	56.66	31	17	54.83	
Peruvian	1595	F.	28¼	18¼	64.91	28	19	67.85	
Asiatics.									
Chinese	956	M.	37	29	78.37	36	27	75.00	

TABLE LXXVIII.—*Synopsis of average indices of section of the femur and of section of the tibia in certain numbers of skeletons in the Army Medical Museum.*

Races.	Average indices of section of femur. No. of femora.	Right side.	No. of femora.	Left side.	Average indices of section of tibia. No. of tibiæ.	Right side.	No. of tibiæ.	Left side.
Sioux Indians	24	112.48	24	110.33	24	69.54	24	69.33
Other North American Indians	23	113.00	21	111.89	23	66.44	22	67.54
Negroes	6	120.53	6	119.10	6	75.00	6	73.00

The following formulæ are found used in the various articles on craniology in the *Zeitschrift für Ethnologie*, from 1879 to 1889, inclusive, to reckon various facial indices. A few articles concerning very small numbers of skulls are omitted. The page given is that on which the article begins. The articles sometimes are made up by two or three men, but Virchow generally writes the craniometrical part.

In these articles (rejecting two articles where, if the formulæ indicated are correct, gross arithmetical errors have been made; also two where the formulæ have been reversed—a clerical error perhaps—and the translation of the article in Italian by Raf. Zampa, where the terminology is a little suspicious) we have the various formulæ occurring as follows:

TABLE LXXIX.

Year.	Page.	Title.	Author.	Formula.
1879	118	Livländische Schädel	Virchow	$\frac{\text{Gesichtshöhe} \times 100.}{\text{Gesichtsbreite (b) Bizygom}}$ and $\frac{\text{Obergesichtshöhe} \times 100.}{\text{Gesichtsbreite (b) Bizygom.}}$
1879	136	Ueber Schädel von Ophrynium	Virchow	$\frac{\text{Gesichtshöhe} \times 100.}{\text{Gesichtsbreite, Sut. zyg. max}}$ and $\frac{\text{Obergesichtshöhe} \times 100.}{\text{Gesichtsbreite, Sut. zyg. max}}$
1879	422	Vier Schädel von Cagraray (Philippinen)	Virchow	$\frac{\text{Mittelgesichtshöhe} \times 100.}{\text{Gesichtsbreite, Malar}}$ and $\frac{\text{Mittelgesichtshöhe} \times 100.}{\text{Gesichtsbreite, jugal.}}$
1880	52	Höhlenschädel aus dem oberen Weichselgebiet	Virchow	$\frac{\text{Gesichtshöhe (b Alveoliar-rand)} \times 100.}{\text{Malarbreite (Bizygom).}}$
1880	121	Schädel von Tebu und Westafrikanern	Virchow	$\frac{\text{Breite des Gesichts} \times 100.}{\text{Höhe des Gesichts.}}$

TABLE LXXIX—Continued.

Year.	Page.	Title.	Author.	Formula.
1881	226	Schädel von Madisonville, Ohio, und von Casabamba, Süd-Colombien.	Virchow ..	$\frac{\text{Gesichtshöhe (a)} \times 100}{\text{Jochbreite.}}$
1881	357	Das Gräberfeld von Slaboszewo bei Mogilno.....	Virchow ..	$\frac{\text{Gesichtshöhe A} \times 100}{\text{Gesichtsbreite A (jugal)}}$ and $\frac{\text{Gesichtshöhe B} \times 100}{\text{Gesichtsbreite A (jugal).}}$
1882	76	Alfuren-Schädel von Ceram und anderen Molucken	Virchow ..	$\frac{\text{Gesichtshöhe (A)} \times 100}{\text{Jugalbreite}}$ and $\frac{\text{Mittelgesichtshöhe (B)} \times 100}{\text{Jugalbreite.}}$
1882	298	Die Weddas auf Ceylon.....	Virchow ..	$\frac{\text{Mittelgesichtshöhe} \times 100}{\text{Jugalbreite.}}$
1883	306	Die Rasse von La Tène	Virchow ..	$\frac{\text{Gesichtshöhe A} \times 100}{\text{Gesichtsbreite A.}}$
1883	331	Eine Fibula aus der Tschetschna und zwei Schädel von Kohan.	Virchow ..	$\frac{\text{Gesichtshöhe B} \times 100}{\text{Gesichtsbreite b, malar.}}$ (N. B.—But both indices are wrong if this is the correct formula.)
1883	390	Schädel der Igorroten	Virchow ..	$\frac{\text{Gesichtshöhe A} \times 100}{\text{Gesichtsbreite a, jugal,}}$ and $\frac{\text{Gesichtshöhe B} \times 100}{\text{Gesichtsbreite b, malar.}}$
1884	181	Hohes Alter der Menschenrassen.....	Kollmann .	$\frac{\text{Gesichtshöhe} \times 100}{\text{Jochbreite}}$ and $\frac{\text{Obergesichtshöhe} \times 100}{\text{Jochbreite.}}$
1884	47	Burgwall bei Ketzin.....	Virchow ..	$\frac{\text{Gesichtshöhe A} \times 100}{\text{Gesichtsbreite A.}}$
1884	113	Das neolithische Gräberfeld von Tangermünde....	Virchow ..	a, $\frac{\text{Gesichtshöhe A} \times 100}{\text{Gesichtsbreite, a, jugal}}$ and b, doubtful.
1884	168	Die Rasse von La Tène	Virchow ..	$\frac{\text{Gesichtshöhe A} \times 100}{\text{Gesichtsbreite a, jugal.}}$
1884	308	Schädel mit zwei Schläfenringen aus Nakel	Virchow ..	$\frac{\text{Gesichtshöhe A} \times 100}{\text{Gesichtsbreite A.}}$
1884	335	Gräberfelder und Urnenfunde bei Tangermünde..	Virchow ..	$\frac{\text{Gesichtshöhe} \times 100}{\text{Gesichtsbreite a, jugal.}}$
1884	390	Anthropologische Excursion nach Feldberg	Virchow ..	$\frac{\text{Gesichtshöhe B} \times 100}{\text{Gesichtsbreite B, malar.}}$
1885	45	Die Bewohner von Süd-Mindanao und der Insel Samal.	Schadenberg.	$\frac{\text{Gesichtshöhe} \times 100}{\text{Gesichtsbreite (Sut. zyg. max.}}$ and $\frac{\text{Obergesichtshöhe} \times 100}{\text{Gesichtsbreite (Sut. zyg. max.}}$ and $\frac{\text{Gesichtshöhe} \times 100}{\text{Jochbreite}}$ and $\frac{\text{Obergesichtshöhe} \times 100}{\text{Jochbreite.}}$
1885	248	Schädel und Skelette von Botocuden am Rio Doce.	Virchow ..	$\frac{\text{Gesichtshöhe A} \times 100}{\text{Gesichtsbreite a, jugal.}}$

TABLE LXXIX—Continued.

Year.	Page.	Title.	Author.	Formula.
1885	283	Pfahlbauschädel des Museums in Bern	Virchow	$\frac{\text{Gesichtshöhe B}\times 100}{\text{Gesichtsbreite b, malar.}}$
1885	314	Reise nach Angra Pequena und Damaraland	Virchow	$\frac{\text{Gesichtsbreite B malar}\times 100}{\text{Gesichtshöhe A.}}$ (N. B.—Formula reversed.)
1885	197	Wedda-Schädel	Virchow	$\frac{\text{Gesichtshöhe B}\times 100}{\text{Gesichtsbreite b, malar.}}$
1886	201	Vergleichende anthropologische Ethnographie von Apulien.	Zampa	$\frac{\text{Gesichtslänge}\times 100}{\text{Gesichtsbreite}}$ and $\frac{\text{Ganze Gesichtslänge}\times 100}{\text{Breite der Wangenpunkte.}}$ (N. B.—Gesichtslänge apparently means both upper and entire facial height.
1886	129	Ausgrabungen an der Insel im See von Jankowo	Virchow	$\frac{\text{Gesichtshöhe}\times 100}{\text{Gesichtsbreite (jugal).}}$
1886	692	Ein Skelet und Schädel von Goajiros	Virchow	$\frac{\text{Gesichtshöhe A}\times 100}{\text{Gesichtsbreite A.}}$
1886	752	Schädel von Baluba und Congonegern	Virchow	$\frac{\text{Gesichtshöhe A}\times 100}{\text{Gesichtsbreite A}}$ and $\frac{\text{Gesichtshöhe B}\times 100}{\text{Gesichtsbreite B.}}$
1887	49	Ueber die Botocudos	Ehrenreich	$\frac{\text{Obere Gesichtshöhe}\times 100}{\text{Jochbreite}}$ and $\frac{\text{Obere Gesichtshöhe}\times 100}{\text{Gesichtsbreite.}}$
1887	296	Motilonen Schädel aus Venezuela	Ernst	$\frac{\text{Gesichtshöhe A}\times 100}{\text{Gesichtsbreite a, jugal}}$ and $\frac{\text{Gesichtshöhe B}\times 100}{\text{Gesichtsbreite b, malar.}}$ (N. B.—Indices wrongly figured.)
1887	321	Gräberfunde von den Key-Inseln, Molucken	Virchow	$\frac{\text{Gesichtshöhe A}\times 100}{\text{Gesichtsbreite A.}}$
1887	354	Gräberfund von Kaweneczyn, Posen	Virchow	$\frac{\text{Gesichtshöhe A}\times 100}{\text{Gesichtsbreite A}}$ and $\frac{\text{Gesichtshöhe B}\times 100}{\text{Gesichtsbreite b.}}$
1887	451	Schädel von Merida, Yucatan	Virchow	$\frac{\text{Gesichtshöhe B}\times 100}{\text{Gesichtsbreite b (malar).}}$
1887	624	Anthropologie der Völker vom mittleren Congo	Mense	$\frac{\text{Gesichtshöhe a}\times 100}{\text{Gesichtsbreite a}}$ and $\frac{\text{Gesichtshöhe b}\times 100}{\text{Gesichtsbreite b.}}$
1888	578	Siamesen-Schädel	Virchow	$\frac{\text{Gesichtshöhe A}\times 100}{\text{Gesichtsbreite a.}}$
1889	170	Schädel von Tenimber und Letti (Timor), Sunda-Inseln.	Virchow	$\frac{\text{Gesichtshöhe A}\times 100}{\text{Gesichtsbreite a}}$ and $\frac{\text{Gesichtshöhe B}\times 100}{\text{Gesichtsbreite a.}}$

TABLE LXXIXa.—*Summary showing frequency of use of the various German indicesin table LXXIX.*

Name of index from "Verständigung."	Formulæ.	No. of articles.
Facial index of Kollmann	Mento nasal height × 100 / Bizygomatic width	22
Upper facial index of Kollmann	Alveolo-nasal height × 100 / Bizygomatic width	8
Facial index of Virchow	Mento-nasal height × 100 / Bimaxillary width	4
Upper facial index of Virchow	Alveolo-nasal height × 100 / Bimaxillary width	14

TABLE LXXIXb.—*Facial indices of Virchow from Europeans.*

Facial	119.1	Upper facial	73.1
Average of	11.0	Average of	27.0

TABLE LXXX.—*Craniometrical data according to Frankfurt agreement, computed from data quoted in Table LXXIX.*

Races.	Length-breadth index.		Length-height index.		Facial index of Kollmann.		Upper facial index of Kollmann.		Facial index of Virchow.		Upper facial index of Virchow.		Nasal index.		Palatine index.		Facial angle.	
	Average.	No. of skulls.	Average.	No. of skulls.	Average.	No. of skulls.	Average.	No. of skulls.	Average.	No. of skulls.	Average.	No. of skulls.	Average.	No. of skulls.	Average.	No. of skulls.	Average.	No. of skulls.
Malays	77.2	28	77.0	25	81.3	8	48.6	16	111.5	3	67.9	24	53.2	28	72.1	22	.....	.....
Veddahs	76.8	5	78.2	5	.....	.....	53.8	3	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Negroes	75.9	21	78.1	12	95.4	6	.....	.....	.....	.....	67.8	15	54.9	19	69.2	17	69° 12′	10
Botocudos	74.5	17	76.2	17	89.1	3	52.6	11	.....	.....	70.0	11	47.3	18	71.3	3	80° 30′	10
Goajiros skulls	81.2	8	73.8	8	83.3	8	.....	.....	.....	.....	.....	.....	47.2	8	72.5	7	.....	.....
Motilo skull	79.0	.....	75.6	.....	80.0	.....	.....	.....	.....	.....	66.0	.....	48.8	.....	78.0	.....	.....	.....
Yucatan skull	90.2	.....	75.7	.....	.....	.....	.....	.....	.....	.....	65.7	.....	49.0	.....	80.3	.....	.....	.....
Calaveras skull	.....	.....	.....	.....	76.3	.....	42.6	.....	.....	.....	.....	.....	58.6	.....	100.0	.....	.....	.....
Rock Bluff skull	74.0	.....	71.5	.....	86.5	.....	47.0	.....	.....	.....	.....	.....	50.9	.....	84.8	.....	.....	.....
Lagoa Santa skulls	72.2	5	80.2	5	84.2	4	47.0	4	.....	.....	.....	.....	50.2	5	98.3	.....	.....	.....

TABLE LXXXI.—*Special series of 101 skulls in the general collection of the Army Medical Museum.*

NOTE.—Frequent reference is made in this work to our series of 101. This is a collection of 101 adult skulls, representing 27 different tribes and races, which we measured exactly on the same system that the Hemenway collection was measured, just previous to commencing the study of the latter. Although it is a small series, we have found it useful for making comparisons in preparing this essay.

The composition of the series of 101 is as follows:

Race or tribe.	Skulls of females.	Skulls of males.	Skulls of unknown sex.	Total.	Race or tribe.	Skulls of females.	Skulls of males.	Skulls of unknown sex.	Total.
Pah Utes	3	4	.....	7	Chuckchees	.....	2	.....	2
Apaches	3	3	.....	6	Japanese	1	1	.....	2
Ancient Californians	5	5	.....	10	Chinese	1	1	.....	2
Cheyennes	1	1	.....	2	Australians	1	1	1	3
Chippewas	1	1	.....	2	Fiji Islanders	1	1	.....	2
Minnetarees	1	1	.....	2	Sandwich Islanders	3	3	.....	6
Navajos	2	2	.....	4	New Zealanders	2	2	.....	4
Pawnees	.....	2	.....	2	Chatham Islanders	1	1	.....	2
Poncas	2	2	.....	4	American Negroes	3	3	.....	6
Seminoles	1	1	.....	2	American Whites	3	3	.....	6
Sioux	2	2	.....	4	Bavarians	1	1	.....	2
Yucatecs	1	1	.....	2	Austrians	3	3	.....	6
Eskimos, Alaskan	1	3	.....	4					
Eskimos, Greenlandic	3	3	.....	6	Total	46	54	1	101
Eskimos, Asiatic	.....	1	.....	1					

TABLE LXXXII.—*General measurements.—Cibola.*

Number of skull.	Greatest length.	Greatest width.	Basi-bregmatic height.	Basi-alveolar radius.	Basi-nasal radius.	Mento-nasal height.	Interorbitary width.	Nasal height.	Nasal width.	Orbital width.	Orbital height.	Profile angle.	Angle of Daubenton.	Occipital angle.	Basilar angle.
												°	°	°	°
H. 201	174	132	133	92	97	.....	.....	44	25	38	31	89	.....	.....	.....
H. 202	165	152	151	95	102	121	108	49	24	43	34	88¼	4½	11	17
H. 203	161	155	146	102	101	123	107	51	26	41	34	85	9	20½	26
H. 204	185	140	138	.....	103	.....	.....	.....	.....	40	33	.....	9	17	22
H. 205	145	140	133	92	92	109	103	49	25	38	34	84	6	18½	24
H. 206	146	141	138	93	91	114	96	50	25	39	36	85	5	15	20
H. 207	163	131	.....	.....	.....	98	95	43	26	39	35	81	.....	.....	.....
H. 208	169	130	.....	.....	.....	109	88	51	23	37	35	87	.....	.....	.....
H. 209	165	123	133	96	97	106	93	47	25	37	34	82	6½	18	24
H. 210	146	142	133	90	90	107	91	44	23	36	34	86½	4	16	21½
H. 211	167	145	147	108	105	124	113	52	28	41	35	85	.....	.....	.....
H. 212	155	146	136	95	95	.....	98	47	26	38	34	80	2	13	18
H. 213	170	142	141	93	101	118	106	48	27	39	36	88	10½	22½	30
H. 214	163	145	.....	.....	.....	109	101	49	26	38	33	88½	.....	.....	.....
H. 215	157	135	135	98	99	112	101	51	25	41	35	87	.....	.....	.....
H. 216	143	144	145	91	95	.....	95	48	24	38	32	88	6	17	23
H. 217	152	146	147	.....	99	.....	100	45	27	40	35	.....	8½	18½	25
H. 218	174	151	147	97	103	.....	107	54	28	40	35	.....	7	18½	24½
H. 219	163	141	144	97	101	.....	88	46	23	36	33	85	.....	.....	.....
H. 220	151	142	138	99	96	118	95	49	23	38	35	85	8½	20½	27½
H. 221	163	133	131	98	96	112	99	50	25	36	34	83	1	10½	14
H. 222	151	134	138	89	97	106	99	47	26	39	36	89	11	22	30
H. 223	166	145	138	97	98	109	94	48	25	37	33	86	1½	11	15
H. 224	148	141	145	100	100	119	101	50	26	40	35	81	13	24½	32
H. 225	152	139	137	.....	.....	112	91	47	24	40	34	83	10½	22	29
H. 226	167	141	145	96	102	120	101	51	24	36	33	91	10	20½	26½
H. 227	147	139	136	88	95	102	100	48	24	37	34	89	4	14½	19½
H. 228	157	146	146	95	97	119	106	50	28	40	36	84	2½	13	17
H. 229	166	129	132	90	96	118	95	51	23	38	35	91½	2	13½	18
H. 230	157	144	134	97	98	114	104	51	26	38	34	85	10½	20½	27
H. 231	162	139	.....	.....	.....	101	92	42	23	37	34	81	.....	.....	.....
H. 232	159	140	137	95	97	118	103	50	28	39	33	84	11	21½	29
H. 233	163	150	144	99	100	122	101	54	25	38	30	88½	5½	16	22
H. 234	159	152	146	95	95	111	97	48	25	35	32	88	7	17	22
H. 235	147	140	138	89	96	106	94	46	24	39	34	86	10	23	31

TABLE LXXXIII.—*Indices of 35 skulls.—Cibola.*

No. of skull.	Cephalic.	Vertico-longitudinal.	Gnathic.	Facial of Virchow.	Nasal.	Orbital.
H. 201	75.86	76.43	94.84	.....	56.81	81.57
H. 202	92.12	91.51	93.13	112.03	48.16	79.06
H. 203	94.51	89.02	100.99	114.95	50.98	82.92
H. 204	75.67	74.05	.....	.....	.....	82.50
H. 205	96.55	91.72	100.00	105.82	51.02	89.47
H. 206	98.63	94.92	98.93	118.75	50.00	92.30
H. 207	80.36	.....	.....	103.15	60.46	89.74
H. 208	76.92	.....	.....	123.86	45.09	94.59
H. 209	74.54	80.60	98.96	113.97	52.19	91.89
H. 210	97.26	91.09	100.00	117.58	52.27	94.44
H. 211	86.82	88.02	102.85	109.73	53.84	85.36
H. 212	94.19	87.74	100.00	.....	55.31	89.47
H. 213	83.52	82.94	92.07	111.32	56.25	92.30
H. 214	88.95	.....	.....	107.92	53.06	86.84
H. 215	85.98	85.98	98.98	110.89	49.01	85.36
H. 216	100.69	101.39	95.78	.....	50.00	84.21
H. 217	96.05	96.71	.....	.....	60.00	87.50
H. 218	86.78	84.48	94.17	.....	51.85	87.50
H. 219	86.50	88.34	96.03	.....	50.00	91.66
H. 220	94.03	91.39	103.12	124.21	46.93	92.10
H. 221	81.59	80.36	102.08	113.13	50.00	94.44
H. 222	88.74	91.39	91.75	107.07	55.31	92.30
H. 223	87.34	83.13	98.97	115.95	52.08	89.18
H. 224	95.27	97.97	100.00	117.82	52.00	87.50
H. 225	91.44	90.13	.....	123.07	51.06	85.00
H. 226	86.22	86.82	94.11	118.81	47.05	91.66
H. 227	94.55	92.51	92.63	102.00	50.00	91.89
H. 228	92.99	92.99	97.93	112.36	56.00	90.00
H. 229	77.74	79.51	93.75	124.21	45.09	92.10
H. 230	91.71	85.35	98.97	109.61	50.98	89.47
H. 231	85.80	.....	.....	109.78	54.76	91.89
H. 232	88.05	86.16	97.93	114.56	56.00	84.61
H. 233	92.02	88.34	99.00	120.79	46.29	78.94
H. 234	95.59	91.82	100.00	114.43	52.08	91.42
H. 235	95.23	93.88	92.70	112.76	52.17	87.17

TABLE LXXXIV.—*Summary of indices of skulls.—Cibola.*

Indices.	Number of skulls.	Maximum.	Minimum.	Average.
Cephalic	35	100.69	74.54	88.86
Vertico-longitudinal	31	101.39	74.05	88.28
Gnathic	28	103.12	91.75	97.18
Facial of Virchow	28	124.21	102.00	113.94
Nasal	34	60.46	45.09	51.88
Orbital	35	94.59	78.94	88.52

H. 220 and H. 229 both show maximum *facial* indices.
H. 208 and H. 229 both show minimum *nasal* indices.

TABLE LXXXV.—*Summary of angles of skulls.—Cibola.*

Angles.	Number of skulls.	Maximum.	Minimum.	Average.
		°	°	°
Profile angle	32	91½	80	85½+
Angle of Daubenton	27	13	1	6½+
Occipital angle	27	24½	10½	17½+
Basilar angle	27	32	14	23½

TABLE LXXXVI.—*Classification of the inion.—Cibola.*

Serial number.	No. of skull.	Class.	Serial number.	No. of skull.	Class.	Serial number.	No. of skull.	
1	H. 201	1	12	H. 213	1	23	H. 225	1
2	H. 202	3	13	H. 215	2	24	H. 226	3
3	H. 203	1	14	H. 216	1	25	H. 227	0–1
4	H. 204	2	15	H. 217	1	26	H. 228	1
5	H. 205	0–1	16	H. 218	4 (?)	27	H. 229	1–2
6	H. 206	0	17	H. 219	2–3	28	H. 230	1
7	H. 208	0	18	H. 220	0–1	29	H. 232	1
8	H. 209	0	19	H. 221	2–3	30	H. 233	1–2
9	H. 210	0	20	H. 222	2	31	H. 234	0
10	H. 211	3–4	21	H. 223	3	32	H. 235	0–1
11	H. 212	1	22	H. 224	1			

In Nos. H. 205, H. 208, H. 209, H. 212, H. 215, H. 220, H. 225, and H. 226 the inion is less prominent than adjoining points on the superior curved line.

TABLE LXXXVII.—*Seriation of the inion in 32 skulls.—Cibola.*

0	5	3	3
0–1	4	3–4	1
1	11	4	1
1–2	2	5	0
2	3		
2–3	2	Total	32

TABLE LXXXVIII.—*Pteria of skulls.—Cibola.*

No. of skull.	Length of right pterion.	Length of left pterion.	No. of skull.	Length of right pterion.	Length of left pterion.
H. 202	14	12	H. 216	.....	7
H. 203	19	24	H. 221	15	12
H. 205	15	17	H. 222	.....	19
H. 206	10	7	H. 223	15	11
H. 207	18	.....	H. 226	10	9
H. 208	15	9	H. 227	13	14
H. 209	15	13	H. 228	17	17
H. 210	17	.....	H. 229	17	16
H. 211	17	19	H. 230	9	13
H. 212	12	11	H. 231	9	11
H. 213	17	16	H. 234	18	11

Average of right pterion = 14.60^{mm}; average of left pterion = 13.55^{cm}. Mean average = 14.07^{mm}. H. 203 has epipteric bone on right side. H. 230 has epipteric bones right and left.

TABLE LXXXIX.—*Showing the character of the Échancrure, or lower nasal border, in 34 skulls.—Cibola.*

Class (Broca).	No. of skulls.	Percentage.	Designation of the skulls.
A	4	11.76	H. 201, H. 218, H. 220, H. 229.
A^1	9	26.47	H. 202, H. 206, H. 209, H. 212, H. 214, H. 215, H. 222, H. 231, H. 234.
$A + A^1$	13	38.23	
B	12	35.27	H. 205, H. 207, H. 208, H. 211, H. 213, H. 216, H. 221, H. 225, H. 226, H. 227, H. 230, H. 235.
C	6	17.64	H. 203, H. 210, H. 217, H. 223, H. 224, H. 228.
D	3	8.82	H. 219, H. 232, H. 233.
E	0	0.00	

TABLE XC.—*Ordination of the angles of torsion of the humeri arranged according to the left humeri.—Cibola.*

	Designation.	Left humeri.	Right humeri.		Designation.	Left humeri.	Right humeri.
		○ /	○ /			○ /	○ /
1	H. 233	143 00	145 00	13	H. 221	160 00	148 00
2	H. 209	149 00	144 00	14	H. 224	160 00	149 00
3	H. 214	150 30	.....	15	H. 216	161 00	158 30
4	H. 207	151 00	136 30	16	H. 227	161 00	157 00
5	H. 213	152 30	137 00	17	H. 226	163 00	146 30
6	H. 217	153 00	.....	18	H. 212	165 00	162 30
7	H. 215	154 00	137 00	19	H. 211	170 00	151 00
8	H. 206	154 30	150 00	20	H. 218	170 00	148 30
9	H. 234	155 00	152 00	21	H. 228	170 30	.....
10	H. 220	157 00	146 00	22	H. 229	171 00	154 00
11	H. 204	157 30	153 00	23	H. 222	178 00	165 00
12	H. 205	158 30	151 00				

Average angle of left humerus=159° 20′.

TABLE XCI.—*Ordination of the angles of torsion of the humeri arranged according to the right humeri.—Cibola.*

	Designation.	Right humerus.	Left humerus.		Designation.	Right humerus.	Left humerus.
		○ /	○ /			○ /	○ /
1	H. 207	136 30	151 00	14	H. 206	150 00	154 30
2	H. 213	137 00	152 30	15	H. 205	151 00	158 30
3	H. 215	137 00	154 00	16	H. 211	151 00	170 00
4	H. 203	143 00	.....	17	H. 234	152 00	155 00
5	H. 209	144 00	149 00	18	H. 204	153 00	157 30
6	H. 233	145 00	143 00	19	H. 202	154 00	.....
7	H. 223	145 30	.....	20	H. 229	154 00	171 00
8	H. 232	145 30	.....	21	H. 227	157 00	161 00
9	H. 220	146 00	157 00	22	H. 216	158 30	161 00
10	H. 226	146 30	163 00	23	H. 208	162 30	.....
11	H. 221	148 00	160 00	24	H. 212	162 30	165 00
12	H. 218	148 30	170 00	25	H. 222	165 00	178 00
13	H. 224	149 00	160 00				

Average angle of right humerus=149° 40′.

Appendix A.

CRANIOMETRICAL DIRECTIONS OF TOPINARD.*

Those which we use, only, are here given.

Essential measurements.

1. Greatest antero-posterior length: From the glabella to the maximum occipital point.
2. Greatest transverse width: Upon the parietal or squamous portion of temporal, no matter where the maximum may fall.
3. Basilo-bregmatic diameter: From the basion to bregma.
4. Smallest frontal width: Shortest distance between the temporal ridges of the frontal bone.
5. Horizontal circumference: Horizontal circumference of the cranium directly above the superciliary ridge and across the most prominent point of the occiput.
7. Naso-basilar line: Nasion to basion.
8. Maximum bizygomatic width: Greatest distance between the zygomatic arches.
9. Biorbital width: Maximum external biorbital or bimalar width from external extremity of small fronto-malar suture to same point opposite.
11. Maximum bimaxillary width: Maximum distance between the inferior extremity of the maxillo-malar suture to the corresponding opposite point.
12. Bigonial width: From the external portion of one angle of the jaw to another.
17. Nasal height or naso-spinal height: From the nasion to the middle of the upper border of the lower nasal spine or lower border of nasal aperture.
18. Maximum width of nasal aperture.
19. Width of orbit: From the dacryon to the opposite external margin following the direction of the grand axis.
20. Height of orbit: Perpendicular to the preceding, beginning at middle of inferior border.
22. Occipito-alveolar length: From the maximum occipital point to the alveolar point.
23. Occipito-spinal length: From the maximum occipital point to the inferior border of the nasal aperture.
24. Capacity of the cranium: Broca's method.

Complimentary measurements.

A. Antero-posterior metopic length: From the metopion to the maximum point of the occiput.
B. Biasteric or maximum occipital width.
C. Bijugular or inferior occipital width.
E. Bitemporal width: From one subtemporal point to another.
F. Vertical circumference or supra-auricular curve: Between the two supra-auricular points, passing upon the bregma.
G. Anterior and posterior parts of horizontal circumference separated by the supra-auricular curve.
H. Interorbital width: Distance from one dacryon to the other.
I. Alveolar external maximum width: Taken at the level of the molar region.

* Topinard: Éléments d'Anthropologie Générale, Paris, 1885, pp. 979, *et seq.*

J. Alveolar external posterior width: Taken at the junction of the exterior arch and the *pan coupé* which is behind the wisdom tooth beneath the articulation of the pterygoid apophysis.
K. Anterior palatine width: Taken between canine and second incisor.
M. Posterior palatine width.
P. Palatine depth.
Q. Height and width of the posterior branch of mandible: Height from angle to upper edge of condyle; width at right angle with the above.
R. External bicondylar width: Taken between the outer edges of the condyles of mandible.
S. Basilo-mental radius.
U. Superior alveolar radius.
V. Nasal radius.
W. Intersuperciliary radius.
X. Metopic radius.
Y. Obelic radius.
Z. Iuial radius.
d. Anterior projection of the cranium or pre-basilar projection.
e. Posterior projection of the cranium or post basilar projection.
f. Superior facial projection or projection of the ophryon.
The above three (*d*, *e*, and *f*) should be taken with regard to alveolo-condylean plane.

APPENDIX B.

CRANIOMETRICAL DIRECTIONS OF THE FRANKFURT AGREEMENT,* AUGUST, 1882.

Those which we use are here given in full, with the numbers, reference letters, etc., which they bear in the original work.

Horizontal plane of cranium indicated by two lines connecting the lowest points of the borders of the orbits with the upper margins of the *meati auditorii* at points perpendicularly above their centers.

1. Horizontal length from the central point between the superciliary ridges to the most prominent part of the occiput on a level with the horizontal plane measured with calipers. The *horizontal length* (L, Figs. 1 and 2) is measured parallel to the horizontal plane, and the taking of this measurement shall be by means of the sliding calipers or Spengel's craniometer. Why this is necessary is significantly shown in Fig. 2. If one takes this measurement with the ordinary calipers, especially on a very long skull with strongly projecting occiput, the result is too small if the measurement is not continued to the tangent, which, rising vertically from the horizontal plane, touches the farthest point of the occiput. This can be done only

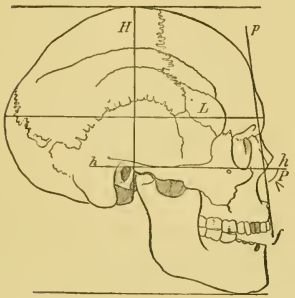


FIG. 1.

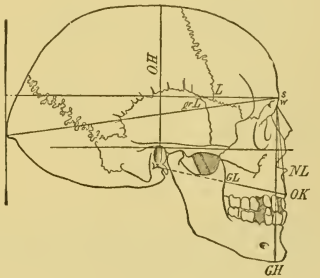


FIG. 2.

with one of the above-mentioned instruments. Indeed, even in their use experience is necessary, and repeated control-experiments. In skulls with full round occiputs the taking of this measurement has no difficulties. As Fig. 1 shows, the most projecting point lies in the same height as the anterior end of L. Respecting this latter point on the glabella (marked S in Fig. 2) a mistake is impossible. Always put the measuring instrument in the median line, therefore, between the superciliary ridges whenever they are separated. As to the *greatest length* (gr. L, Fig. 2), it is apparent, upon a comparison of Figs. 1 and 2, that a difference between this and the horizontal length can only occur in skulls with very prominent occiputs. In the full, rounded occiput of Fig. 1 both lengths are identical. The sliding calipers and ordinary calipers, accurately applied, give then the same result. In the extreme case taken in Fig. 2 the difference, with a length of 206^{mm} for the brain capsule, amounts to 5^{mm}. Also, the skull length measured from the line of the frontal protuberance, the *intertuberal length*, coincides in its results very nearly with the greatest length and horizontal length, especially in brachicephalic skulls with well-rounded foreheads.

* Archiv für Anthropologie, Bd. XV, 1881, pp. 1–8.

2. Greatest length (longitudinal diameter) from the center point between the superciliary ridges to the most prominent part of the occiput (without regard to horizontal plane); calipers.
3. Intertubal length from the central point between the frontal eminences and the most prominent part of the occiput (without regard to the horizontal plane); measured with calipers.
4. Greatest width, B. B., Fig. 3, perpendicular to sagittal plane, measured with calipers (not over the mastoid processes or at the posterior temporal ridge); the points measured must be on the same horizontal plane.
5. Smallest frontal breadth, S. S., Fig. 4; shortest distance between the temporal ridges of the frontal bone.
6. Height, called entire height after Virchow, H, Fig. 1: From the center of the anterior border of the foramen magnum to the parietal curve, perpendicular to horizontal plane. The difference between the height of the posterior border of the foramen magnum and the anterior should be indicated from which the height according to Baer Ecker is ascertained. (Meas ured with calipers.)
7. Auxiliary height: As in crania, in which the bones of the face are missing, the horizontal plane can not be accurately indicated, the following shall be measured as the auxiliary height: From the center of the anterior border of the foramen magnum to junction of coronal and sagittal sutures; this always nearly corresponds with the height as in 6.

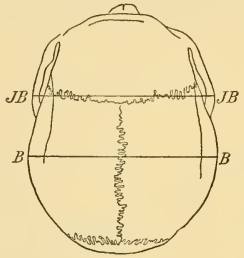


Fig. 3.

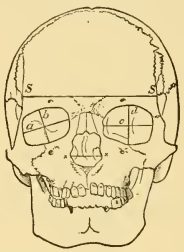


Fig. 4.

8. Auricular height: From the upper margin of the meatus auditorius to a point of the vertex perpendicularly above the meatus, perpendicular to the horizontal plane.
9. Auxiliary auricular height: From the same starting point to the highest point of the parie al curve, about 2 or 3 centimeters behind the coronal suture.
10. Length of cranial basis: From the center of the anterior border of the foramen magnum to the middle of the naso-frontal suture. (Measured with calipers.)
12 and 13. Greatest length and breadth of foramen magnum to be measured in the sagittal plane and perpendicular thereto.
13*a*. Breadth of cranial basis: Distance between the ends of the mastoid processes.
14. Horizontal circumference of cranium: Directly above the superciliary ridge and over the most prominent part of the occiput. Steel-tape.
15. Sagittal circumference of cranium: From the naso-frontal suture to the posterior margin of the foramen magnum along the sagittal suture. Steel-tape.
16. Vertical circumference from one upper margin of the meatus auditorius to the other, perpendicular to horizontal plane (about 2 or 3 centimeters behind coronal suture). Steel-tape.

LINEAL MEASURES OF FACE.

17. Facial width after Virchow: Distance between the maxillo-malar sutures; should be measured from the lower anterior corner of one malar bone to the other.
18. Zygomatic width: Greatest distance between the zygomatic arches.
18*a*. Interorbital width: Shortest distance between the inner borders of the orbits.

19. Facial height from the center of the fronto-nasal suture to the center of the lower border of the inferior maxilla. (G. H.—W, Fig. 2.)
20. Upper (or middle) facial height: From the middle of the naso-frontal suture to the middle of the alveolar edge of the superior maxilla, between the middle incisors. (O. K.—W, Fig. 2.)
21. Nasal height (W.—N. H., Fig. 2): From the middle of the naso-frontal suture to the middle of the upper border of the lower nasal spine.
22. Greatest breadth of nasal cavity (wherever it is found, see Fig. 4) to be measured horizontally.
23. Greatest breadth of orbit (*a* Fig. 1): From middle of median border to lateral border of orbit.
25. Greatest height of orbit (Fig. 4, *b*): Perpendicular to greatest breadth.
27. Length of palate bone: From the extreme point of the posterior nasal spine to the inner lamella of the alveolar border between the middle incisors.
28. Median width of palate: Between the inner alveolar walls of the second molars.
29. Width of posterior end of palate: On both posterior ends of palate, between the inner alveolar walls.
30. Length of profile of face) Kollmann's (G. L., Fig. 2): From the most prominent part of the middle of the external alveolar border of the upper maxilla to the anterior margin of the foramen magnum (in the median plane).
31. Profile angle (P<, Fig. 1) is the angle formed by profile line Pf with the horizontal.

MEASUREMENT OF CAPACITY OF CRANIUM.

32. The capacity of the cranium is measured with shot (in fragile crania with millet). The manner of measuring to be agreed upon hereafter.

CRANIAL INDICES.

I. Length-width index $\frac{100 \text{ width}}{\text{length.}}$

Dolichocephalic	to 75.0
Mesocephalic	75.1—79.9
Brachycephalic	80.0—85.0
Hyperbrachycephalic	from 85.1 and over.

II. Length-height index $\frac{100 \text{ height}}{\text{length.}}$

Chamæcephalic (flat crania)	to 70.0
Orthocephalic	70.1—75.0
Hypsicephalic (high crania)	75.1 and over.

III. Profile angle.

The inclination of the profile line to the horizontal is divided in the following three grades:

1. Prognathic	to 82.0
2. Mesognathic or orthognathic	83.0—90.0
3. Hyperorthognathic	91.0 and above.

IV. Facial index (after Virchow) $\frac{100 \text{ facial height}}{\text{facial width,}}$ calculated from the linear distance of the facial breadth (No. 17) and the facial height (No. 19) (like the facial index of von Hölder).

Broad-face crania	to 90.0
Small-face crania	90.1 and over.

V. Upper facial index (after Virchow) $\frac{100 \text{ upper facial height}}{\text{facial width.}}$ calculated from the linear distance of the facial width (No. 17) and the upper facial height (No. 20).

Broad upper face crania, index	to 50.0
Narrow upper face crania, index	50.1 and over.

VI. Zygomatic face index (after Kollmann). $\frac{100 \text{ facial height.}}{\text{Zygomatic breadth.}}$ calculated from the greatest distance between the zygomatic arches (No. 18) and facial height (No. 19), gives two grades:

Low, chamæprosopic, face crania	to 90. 0
High, leptoprosopic, face crania	90. 1 and above.

VII. Zygomatic upper face-height index (after Kollmann). $\frac{100 \text{ upper face height.}}{\text{Zygomatic breadth.}}$

Chamæprosopic upper face with index	to 50. 0
Leptoprosopic upper face with index	50. 1 and above.

VIII. Orbital index. $\frac{100 \text{ orbital height.}}{\text{Orbital width.}}$

Chamækonchic	to 80. 0
Mesokonchic	80. 1—85
Hypsikonchic	85. 1 and over.

IX. Nasal index. $\frac{100 \text{ width of nasal cavity.}}{\text{Nasal height.}}$

Leptorrhinic	to 47. 0
Mesorrhinic	47. 1—51. 0
Platyrrhinic	51. 1—58. 0
Hyperplatyrrhinic	58.1 and over.

X. Palate index (after Virchow). $\frac{100 \text{ palate breadth.}}{\text{Palate length.}}$

Leptostaphylin	to 80. 0
Mesostaphylin	80. 1—85. 0
Brachystaphylin	85. 1 and over.

Appendix C.

DETERMINATION OF THE AGE OF SKULLS.

[Abridged from Broca's Instructions*.]

There are to be distinguished the following periods: First period of childhood, second period of childhood, adult age, ripe age, senility. These indications are enough and are worth more than those of years of age because the anatomical and physiological phenomena which they demonstrate are more or less precocious according to individuals or according to race. In our race these periods correspond nearly to the following ages:

First period of childhood, from birth to the end of the sixth year:	
Second period of childhood	7 to 14 years.
Youth	14 to 25 years.
Adult age	25 to 40 years.
Ripe age	40 to 60 years.
Senility	beyond 60 years.

We give these figures as a concession to custom and to make the succession of the periods more easily appreciated. But let us hasten to add that they are for the most part very uncertain. * * *

First period of childhood.—From birth to the eruption of the first great molars, called sixth year's teeth. * * *

Second period of childhood.—It commences at about the age of six years with the eruption of the first permanent molar, which marks the beginning of the second dentition; it ends about the age of thirteen or fourteen years, when the eruption of the four second permanent molars is completely achieved. * * *

Youth.—It commences when the eruption of the four second permanent molars is completely achieved—that is to say, when the crowns of these teeth are altogether on a level with those of the first molars; it is finished when on the one hand the wisdom teeth are come out, and when on the other hand the basilar suture is completely closed.

Adult age, ripe age, and senility.—Onward from the end of the third period the distinction of ages is much more doubtful. It is based upon the observation of two phenomena which are gradual and very irregular in their chronology. * * *

Physiologically one is generally contented to divide all the time which passes from the end of youth to death into two periods: The period of gradual change, called indifferently virility, adult age, or ripe age, and the period of decadence, called senility. In craniology the first of these periods should be divided in two ages: Adult age, comprised between the end of youth and the beginning of the ossification of the sutures, and the period of gradual change from then on to senility. The craniological distinction between adult age and ripe age is generally easy since it rests upon the anatomical observation of the study of the sutures. * * *

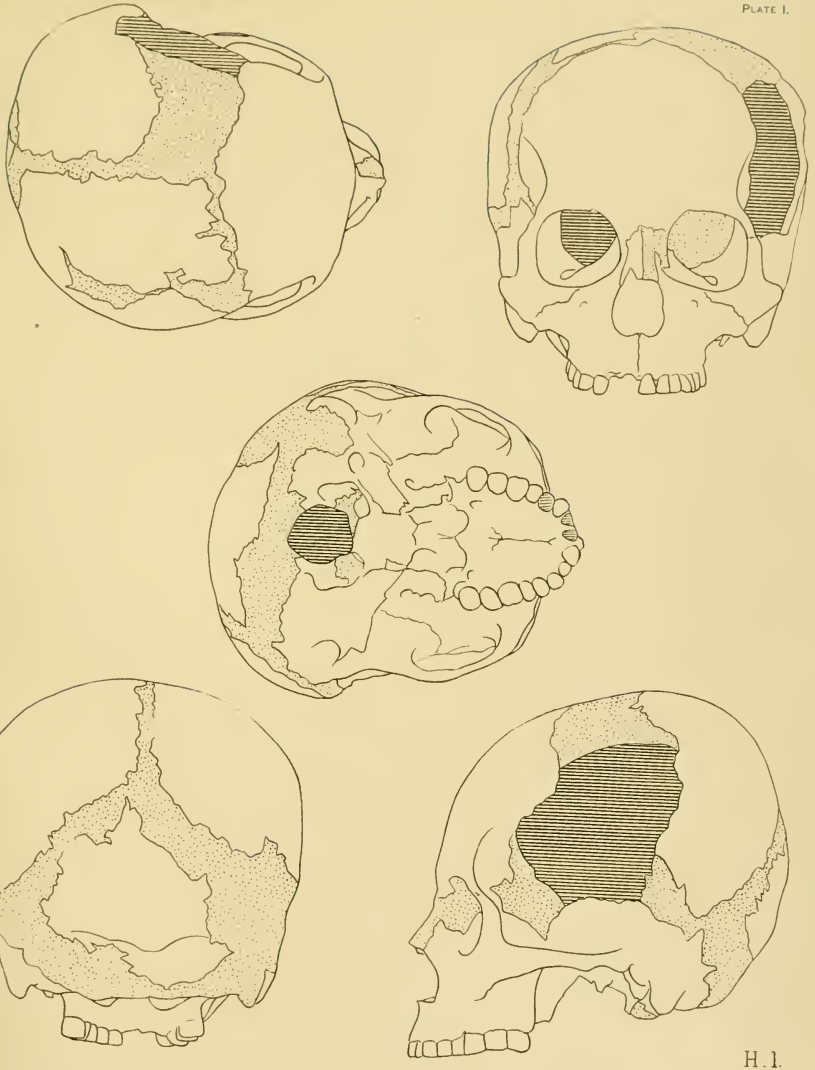
Senility of the skull is recognized by the following characters:

First. The sutures are mostly in an advanced or complete state of ossification; some of them at least are entirely effaced and may have left not even a vestige. The others, with the exception of the squamous suture, which sometimes remains open until a very advanced age, are more or less ossified. * * *

* Instructions craniologiques et craniometriques par P. Broca, Paris, 1875, pp. 128 *et seq.*

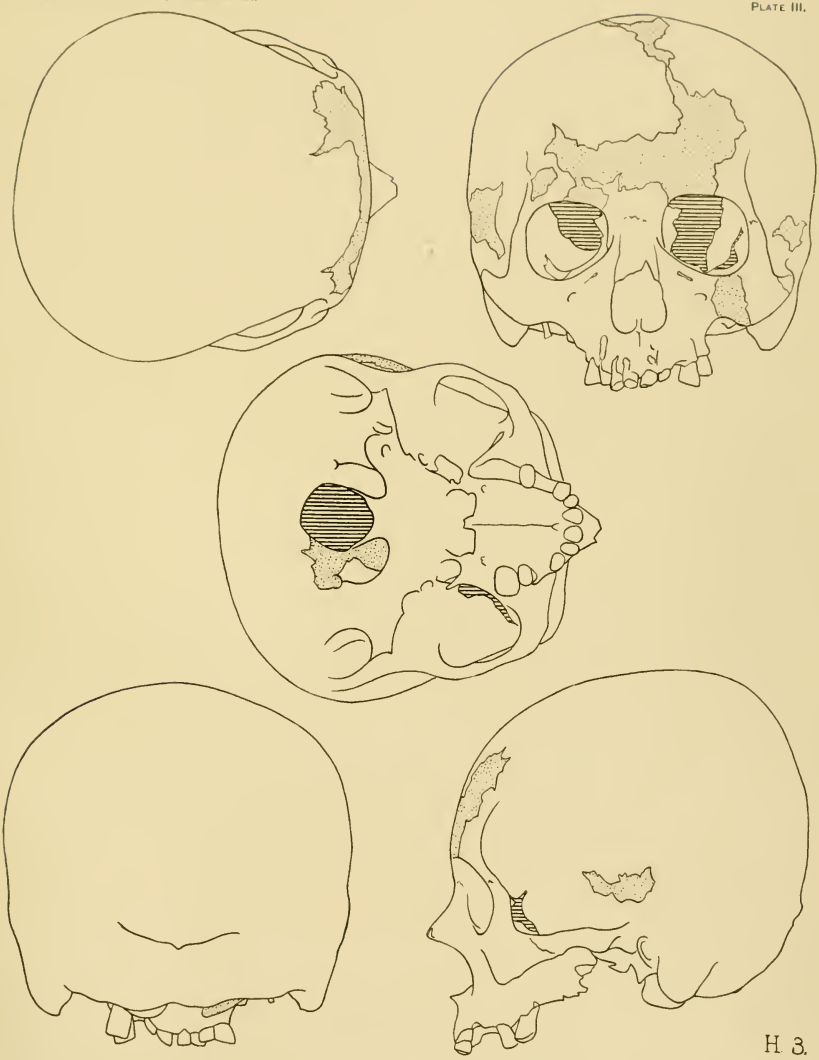
Second. The wearing away of the teeth which are yet in place is very pronounced. * * * The *alveolar point* mounts almost up to the level of the nasal spine; the mandible reduces itself to its *basilar portion;* the height of the symphysis of the chin is found reduced more than one-half, and finally the *angle of the jaw* becomes very obtuse. * * *

Third. The bones of the cranial vault of old persons sometimes are subject to an interstitial resorption of the spongy tissue; the two compact tables of the bone become fused in one compact and semitransparent plate, and from this result the undulating depressions characteristic of *senile atrophy,* which are the certain signs of an advanced old age. The most ordinary seat of these senile atrophies is the zone of the parietal comprised between the sagittal sature and the superior temporal line of that bone.

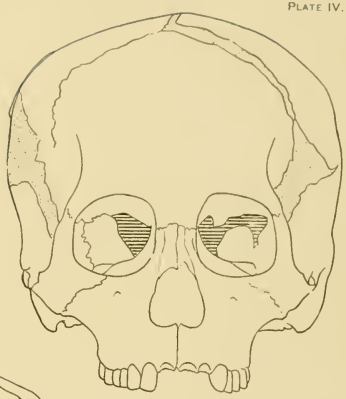


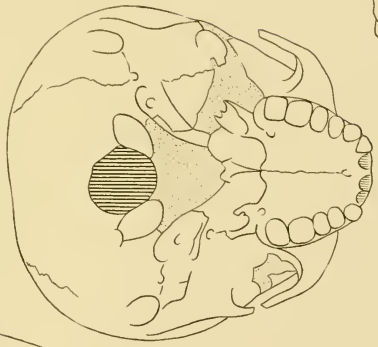
H. 1.

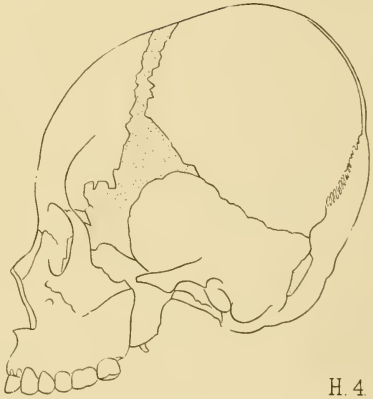
H. 2.



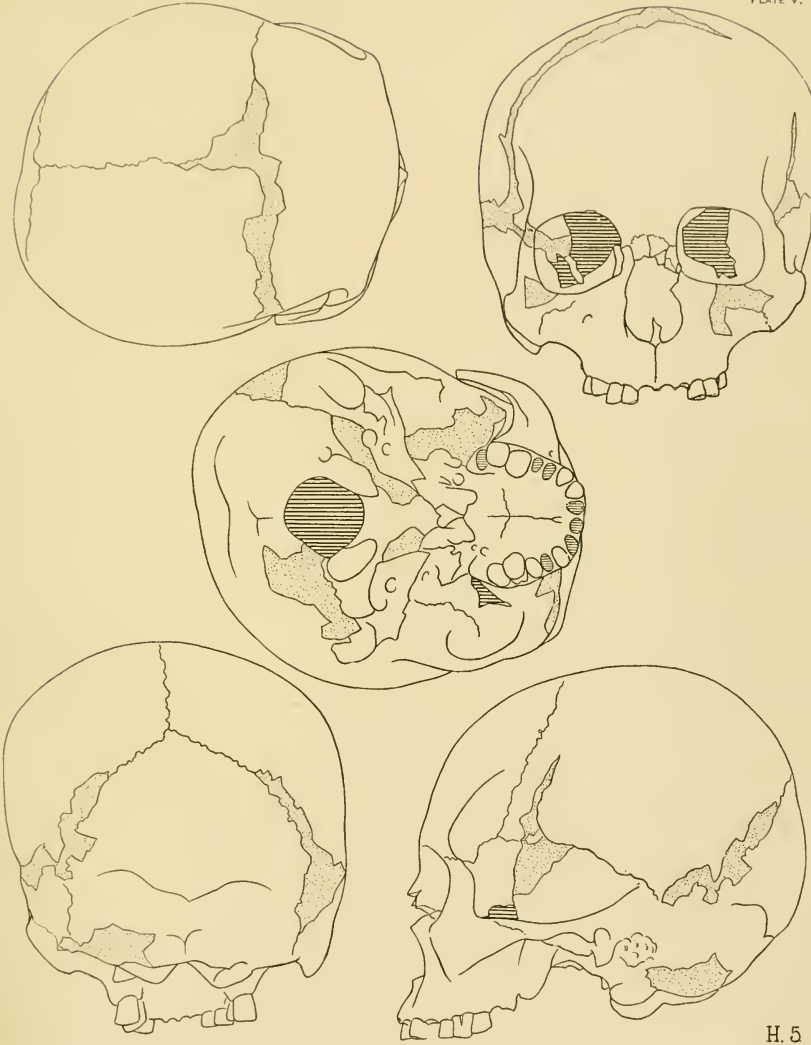
H 3.



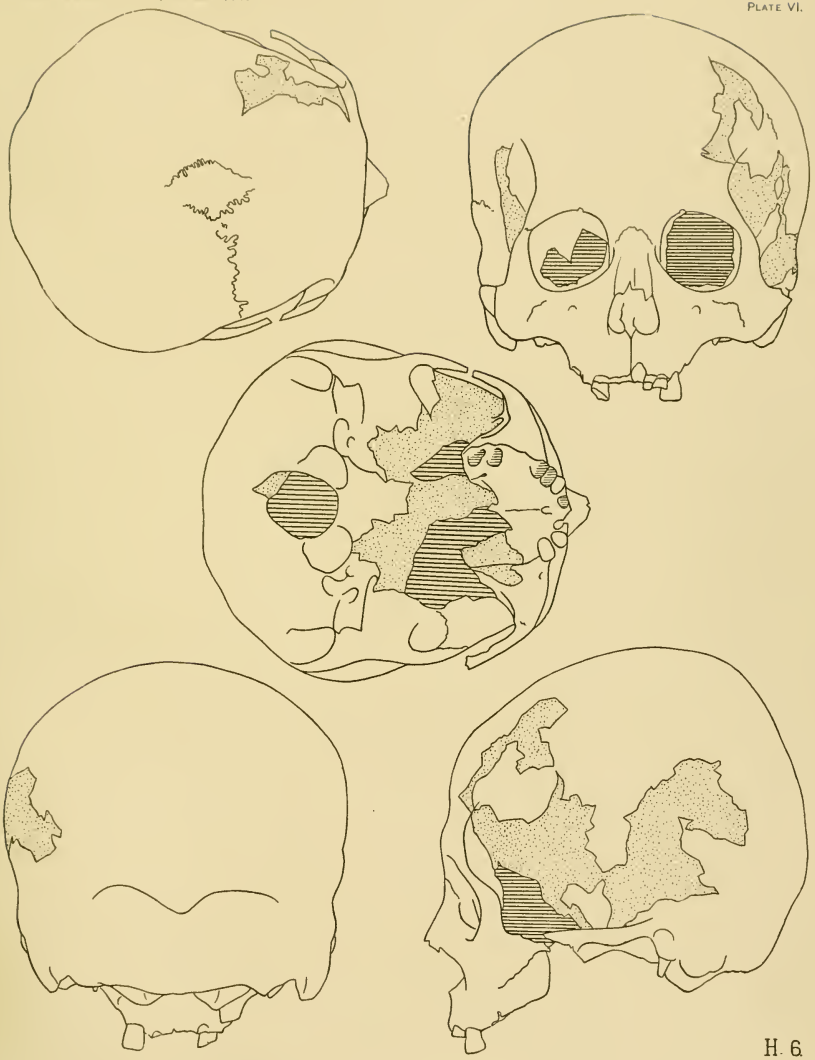




H. 4.



H. 5



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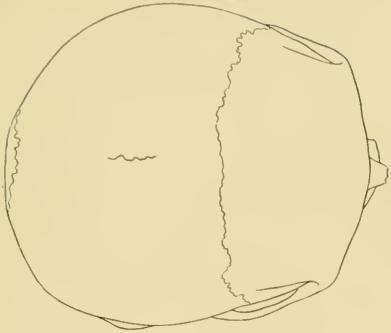
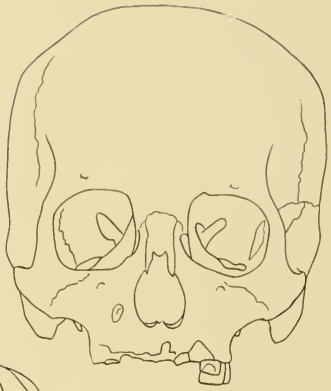
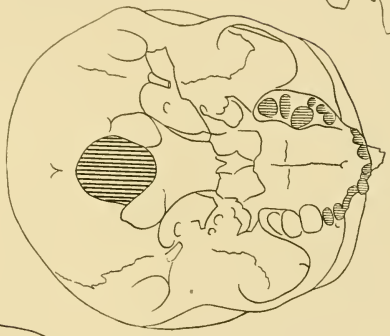
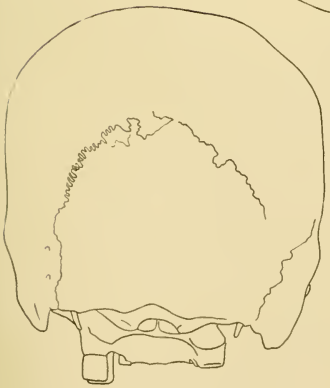
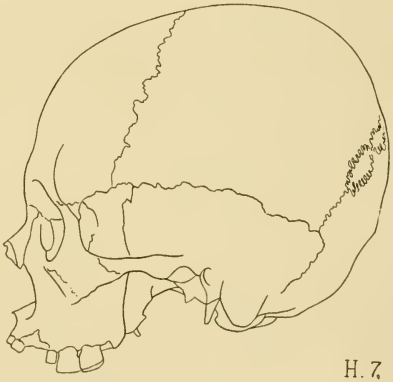


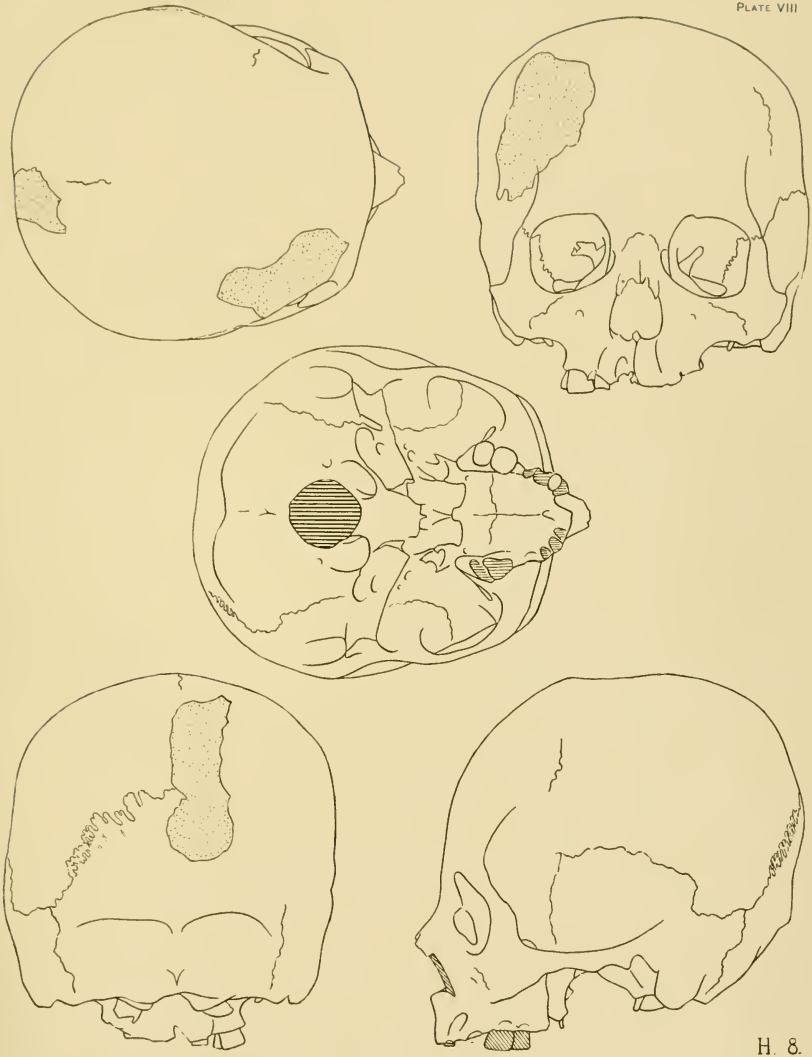








H. 7.



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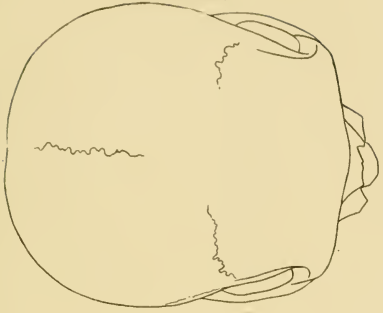

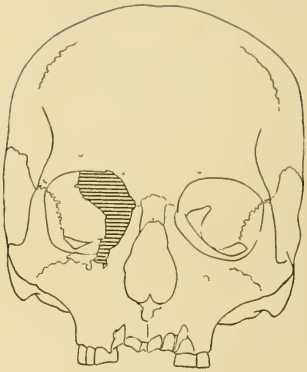

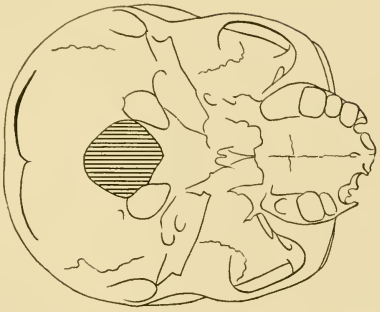

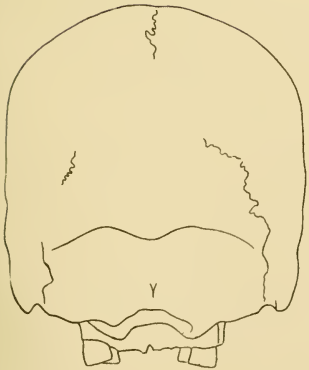

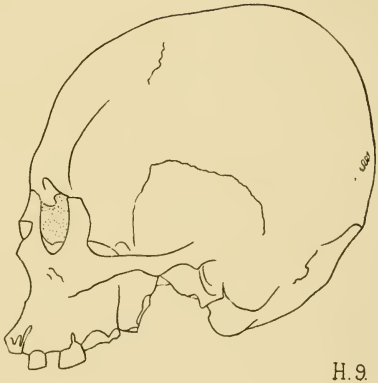

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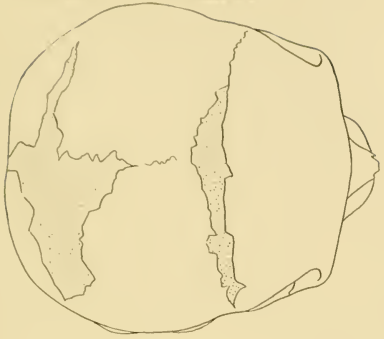

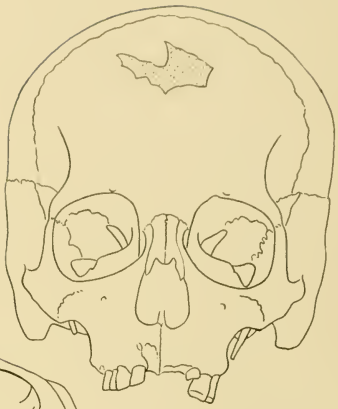

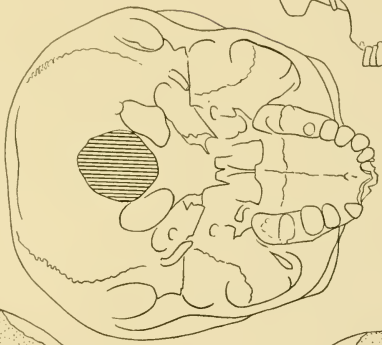

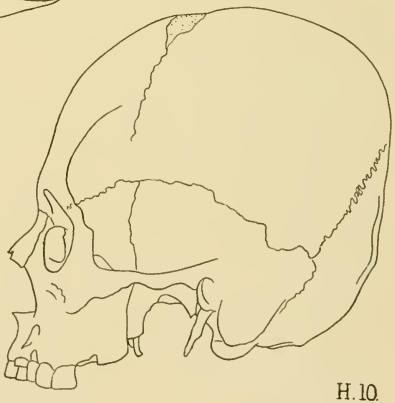

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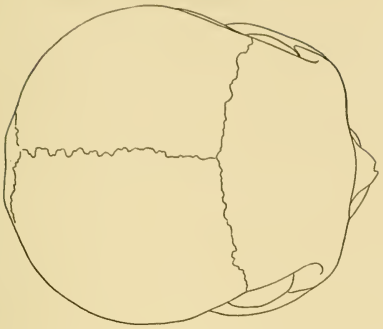

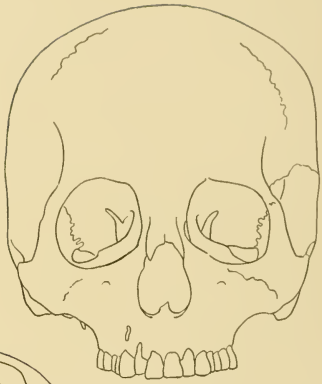

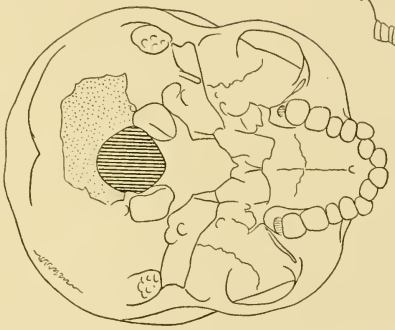

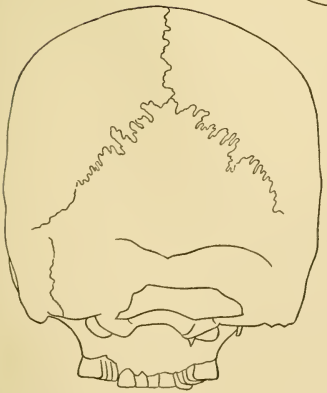

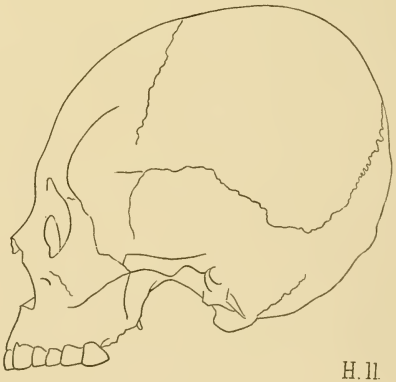

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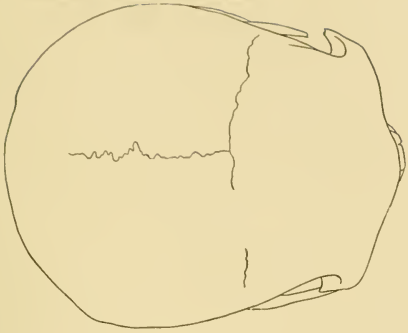

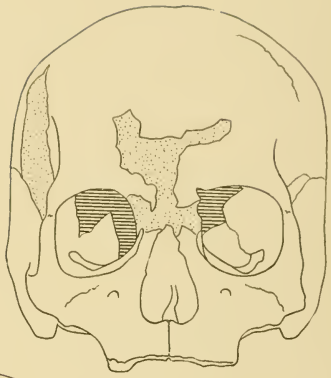

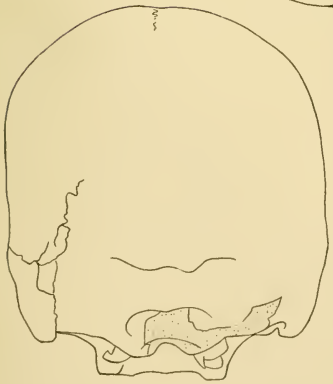

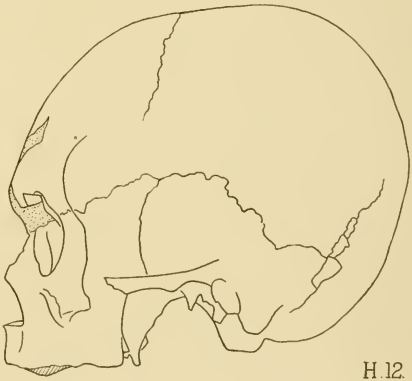

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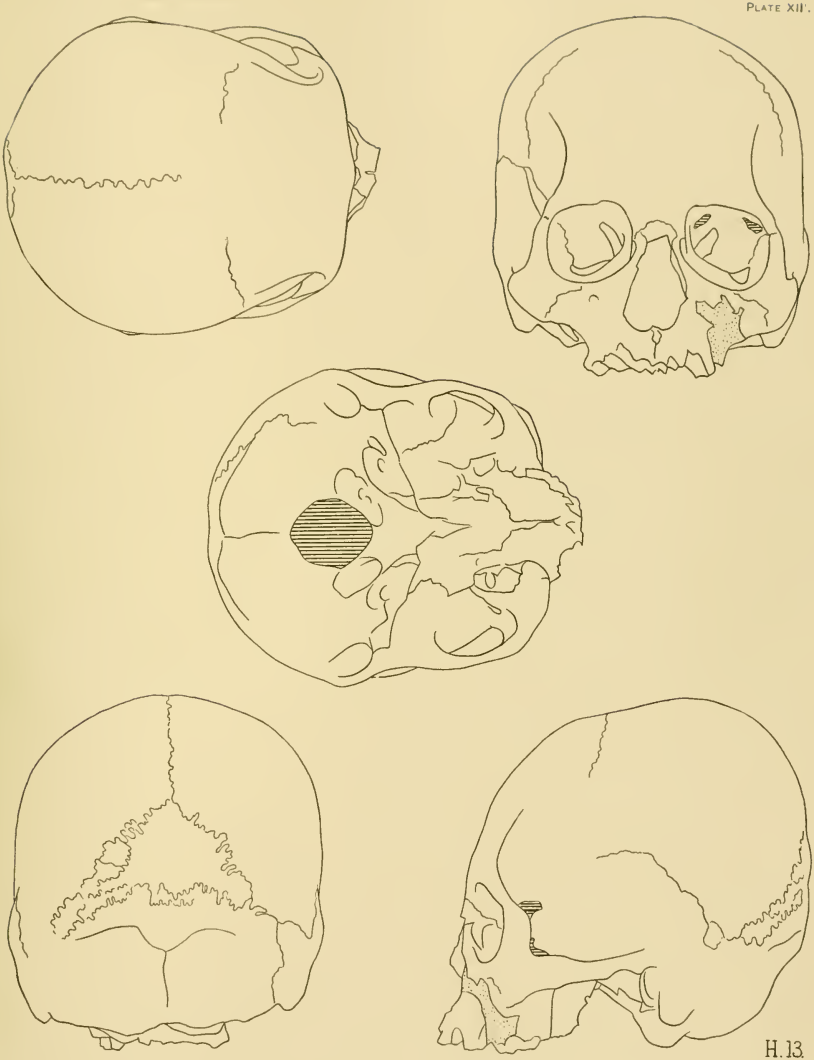

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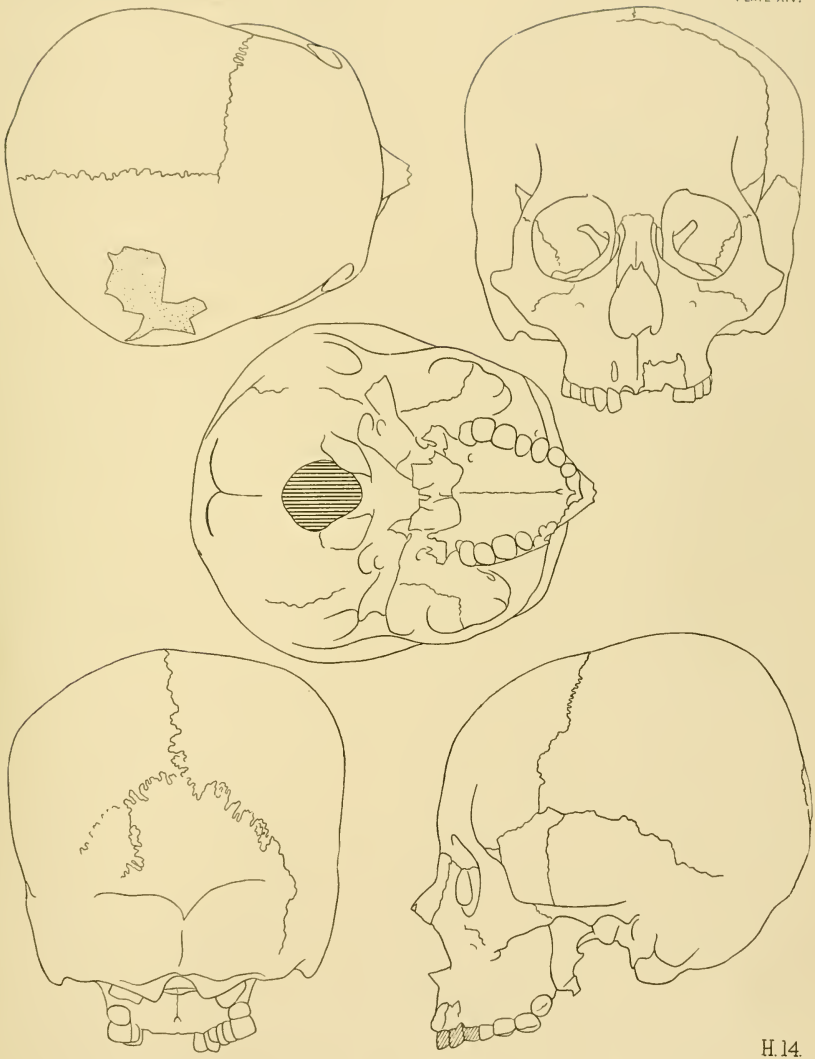

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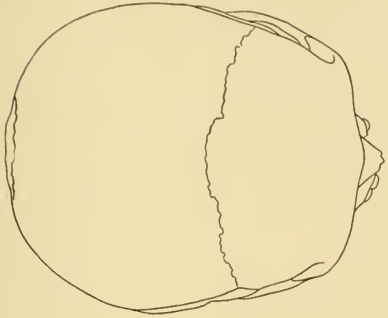

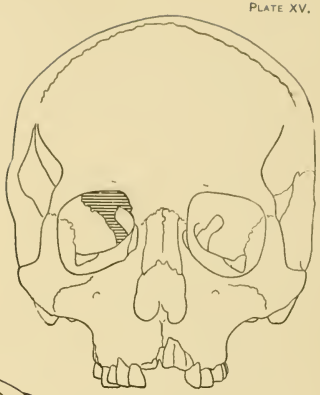

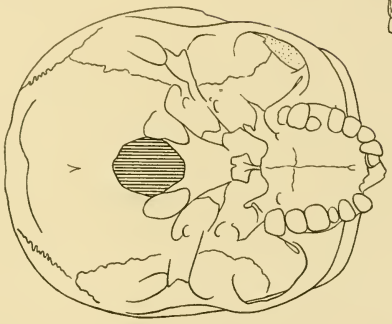

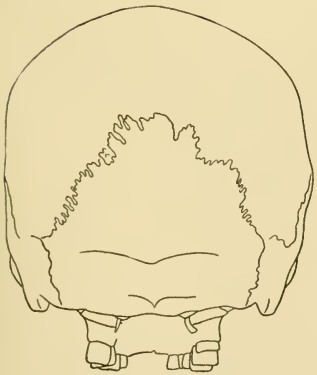

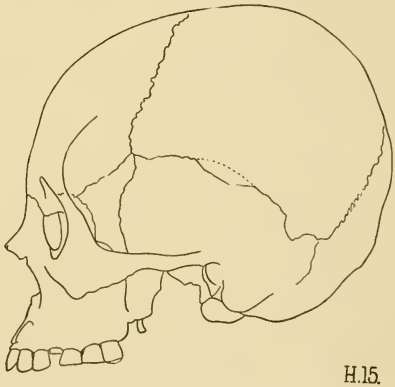

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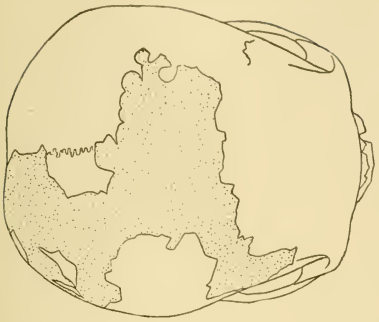

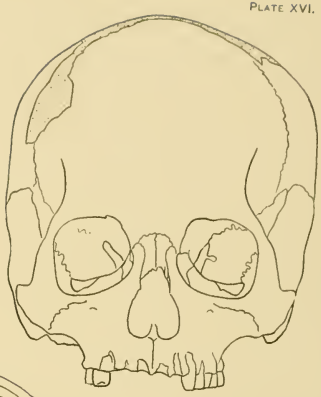

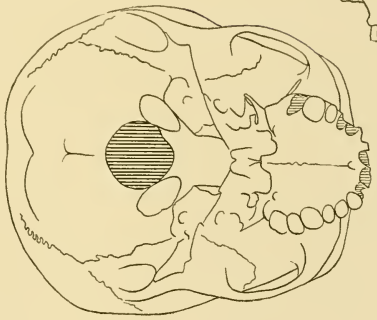

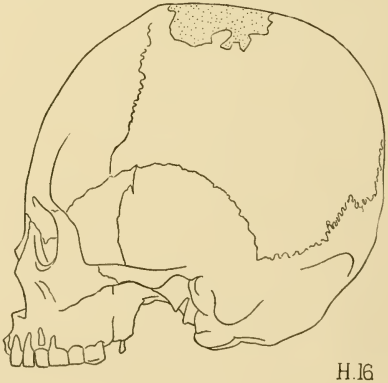

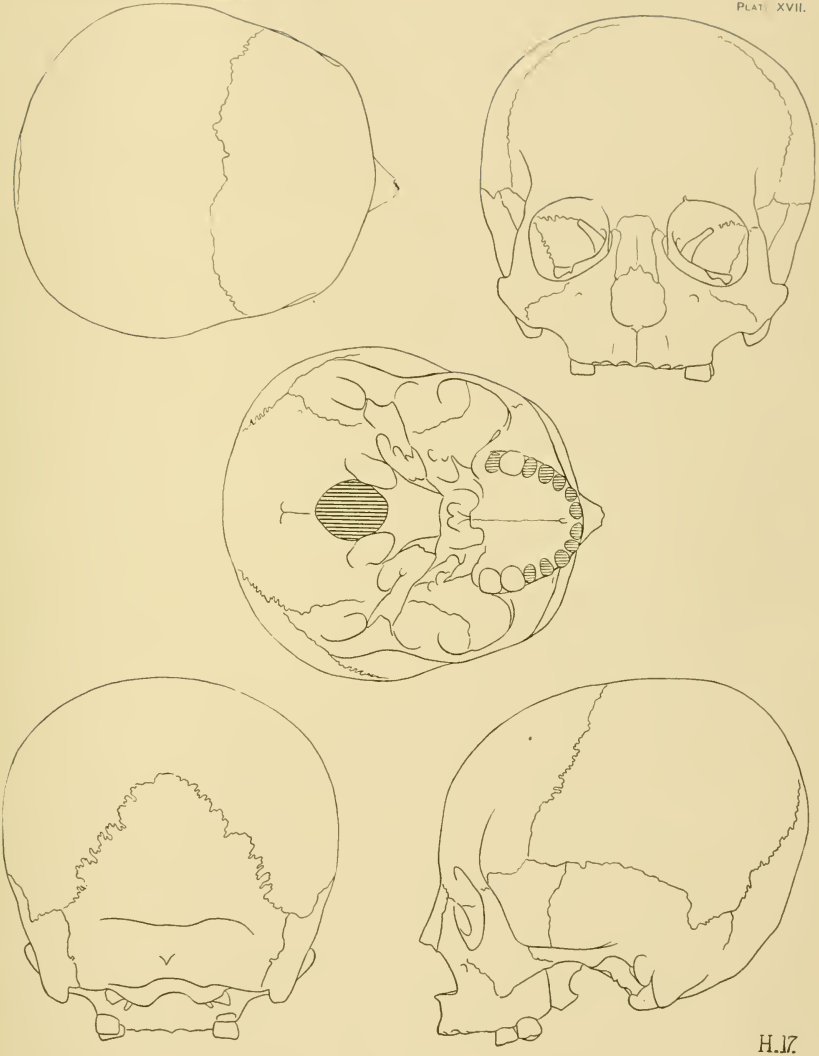

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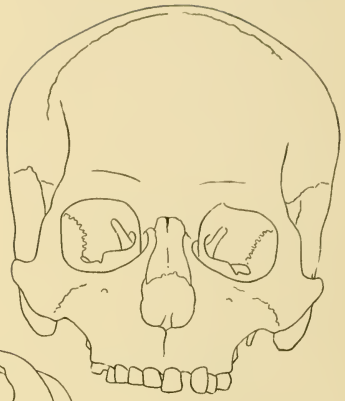

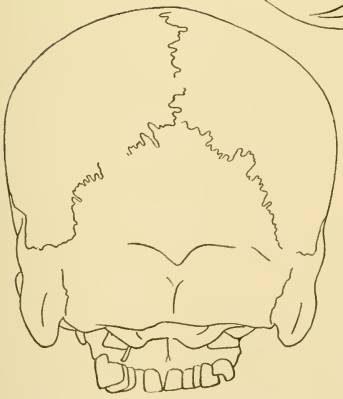

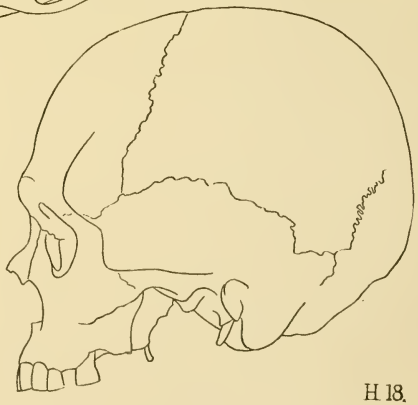

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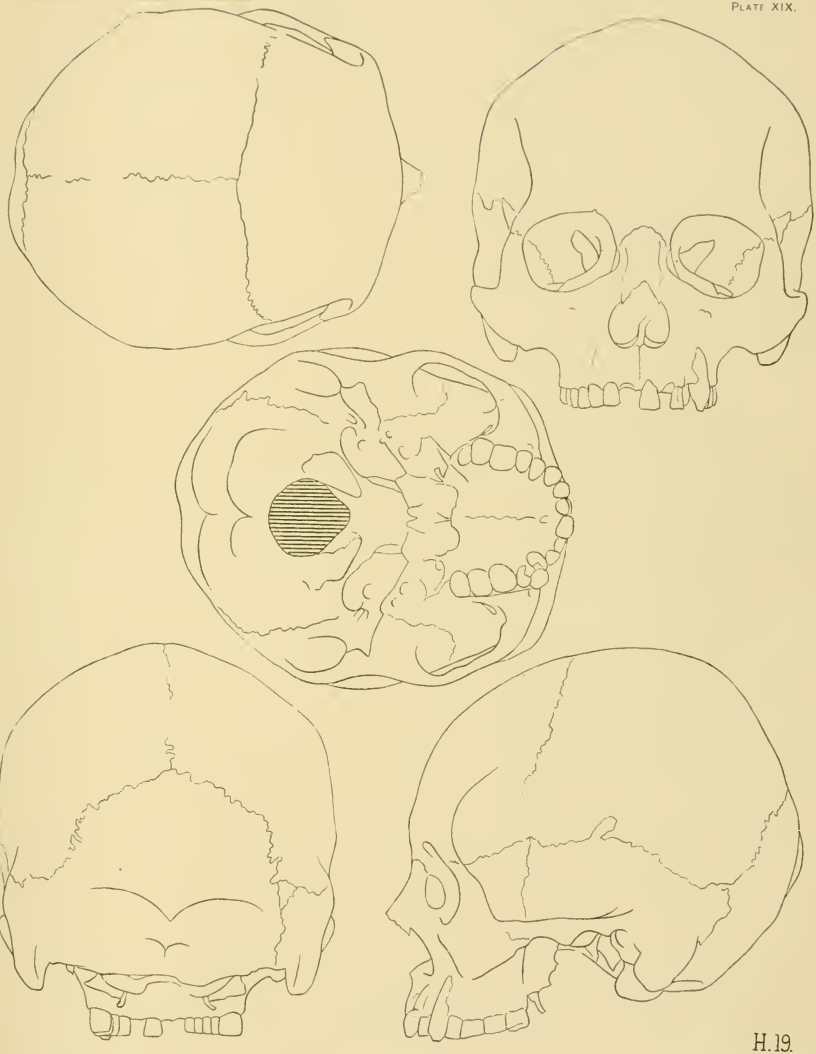

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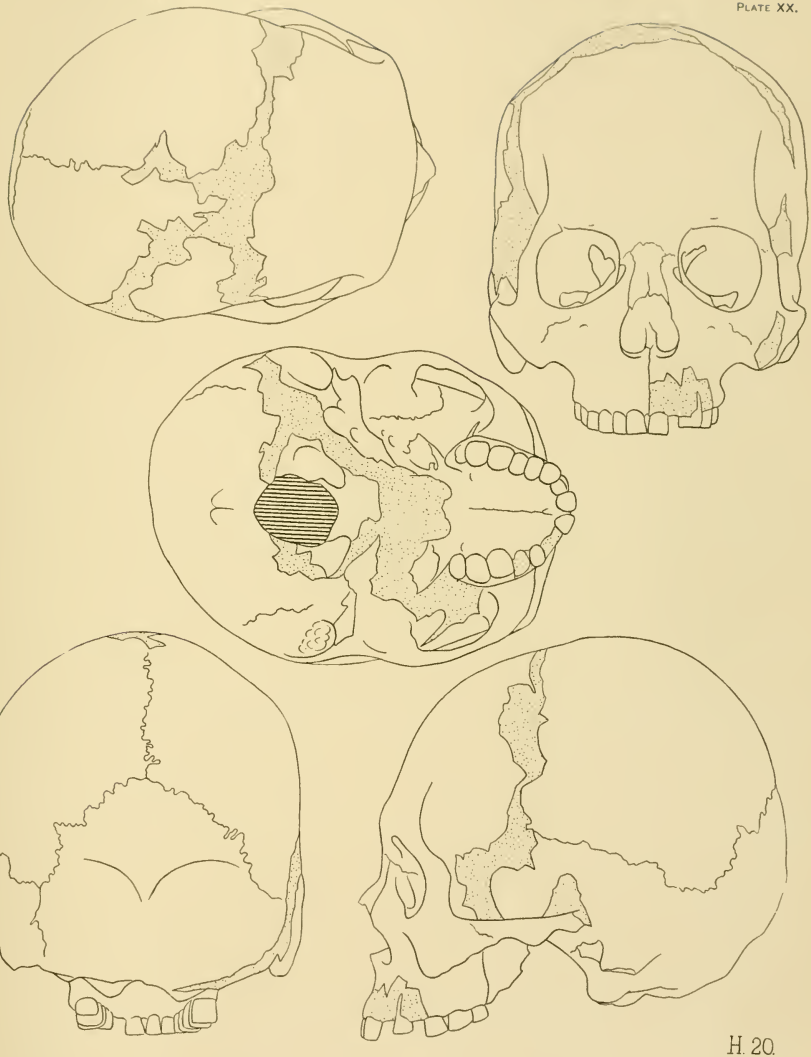

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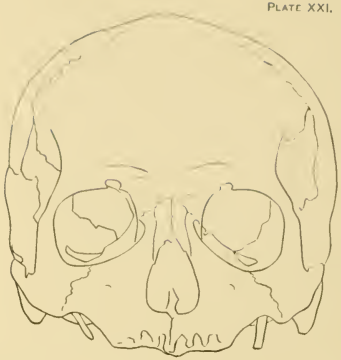

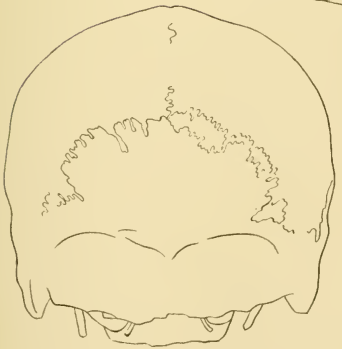

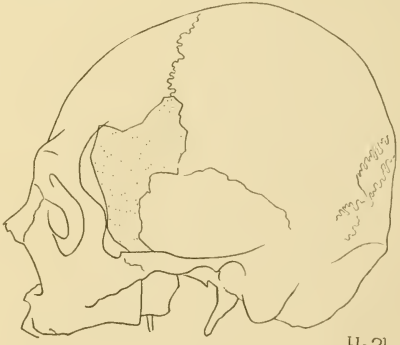

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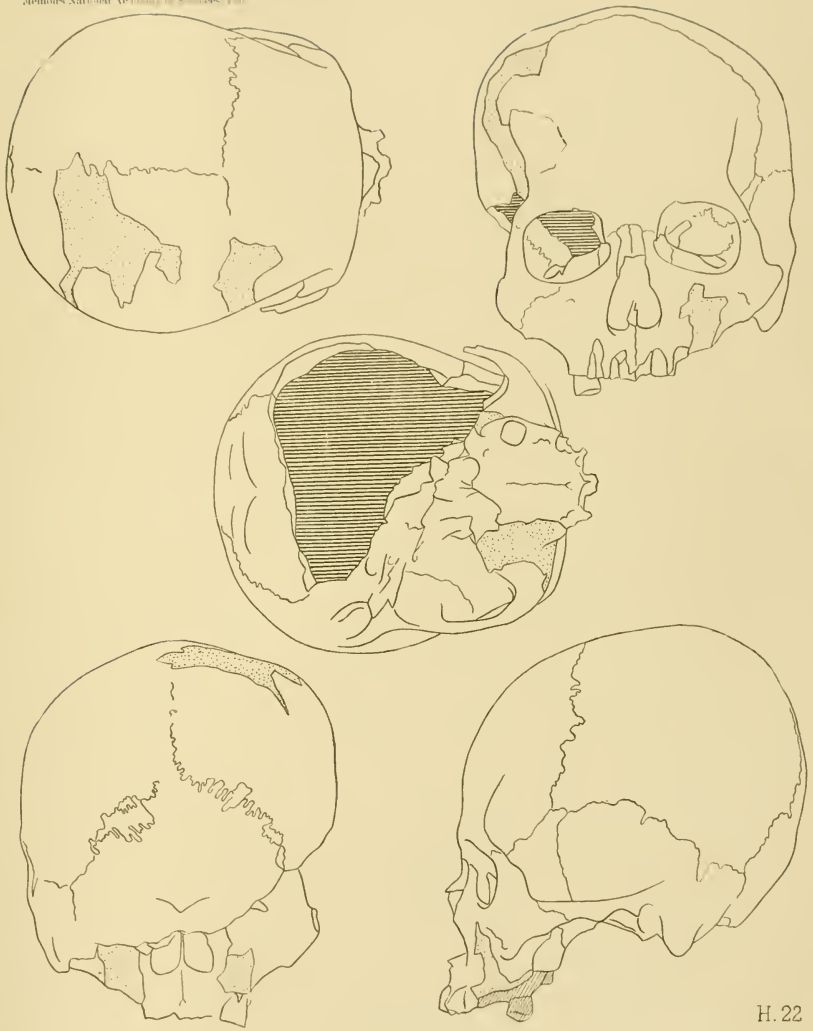

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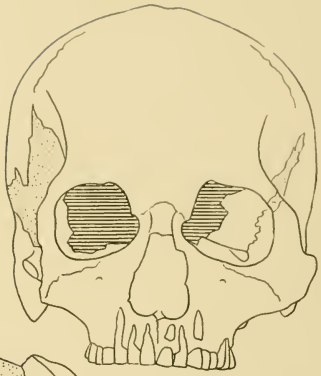

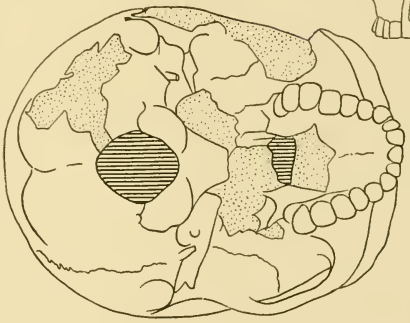

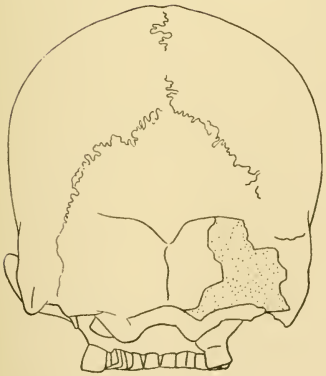

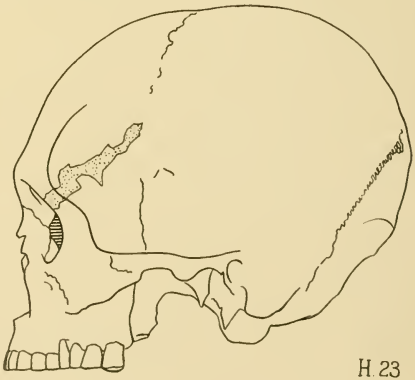

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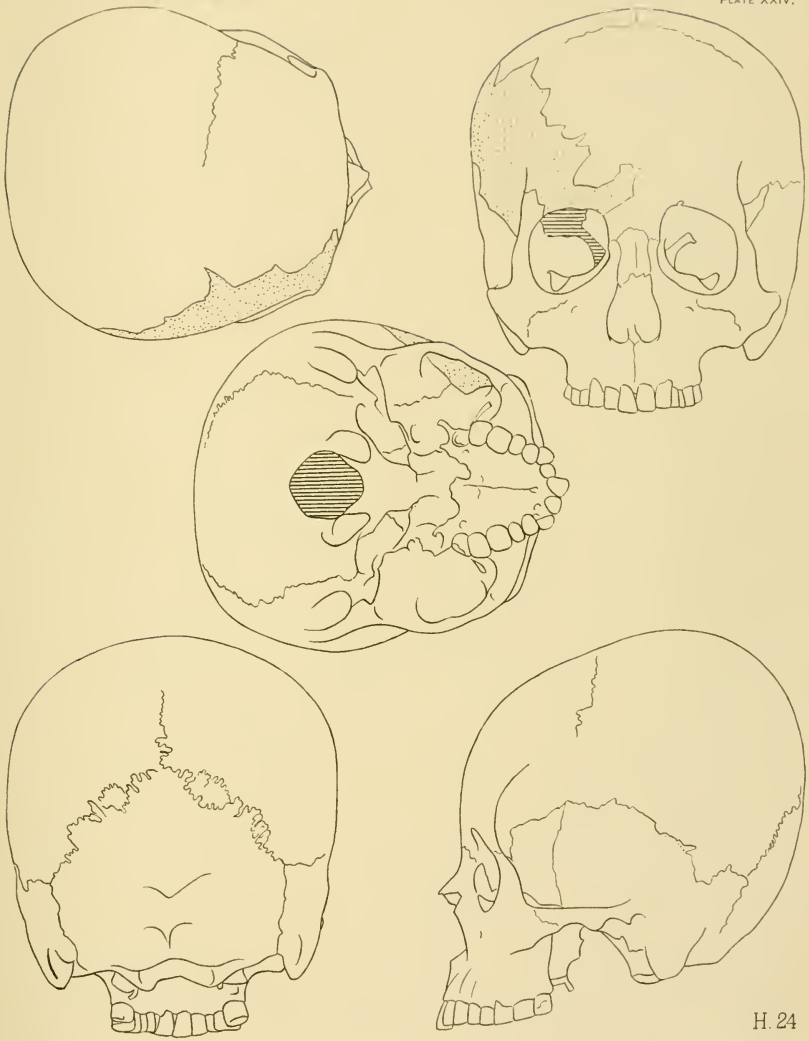

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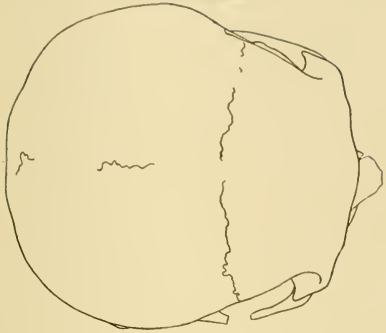

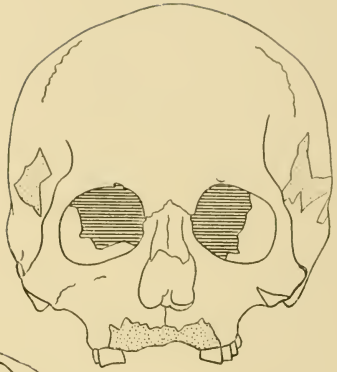

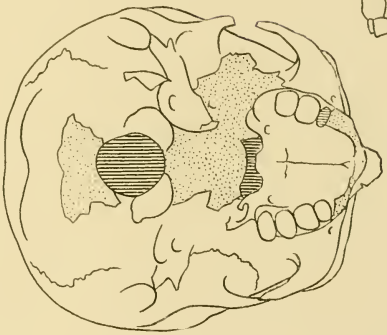

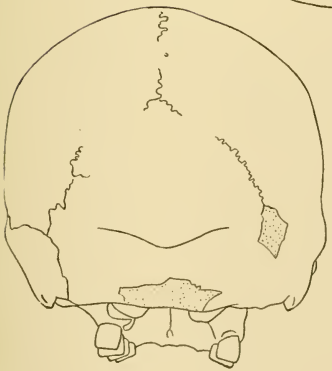

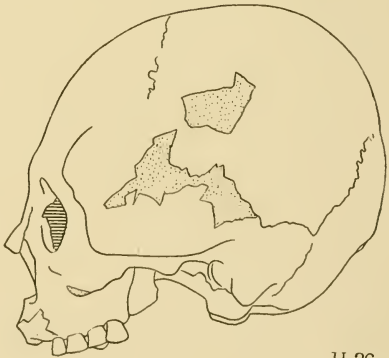

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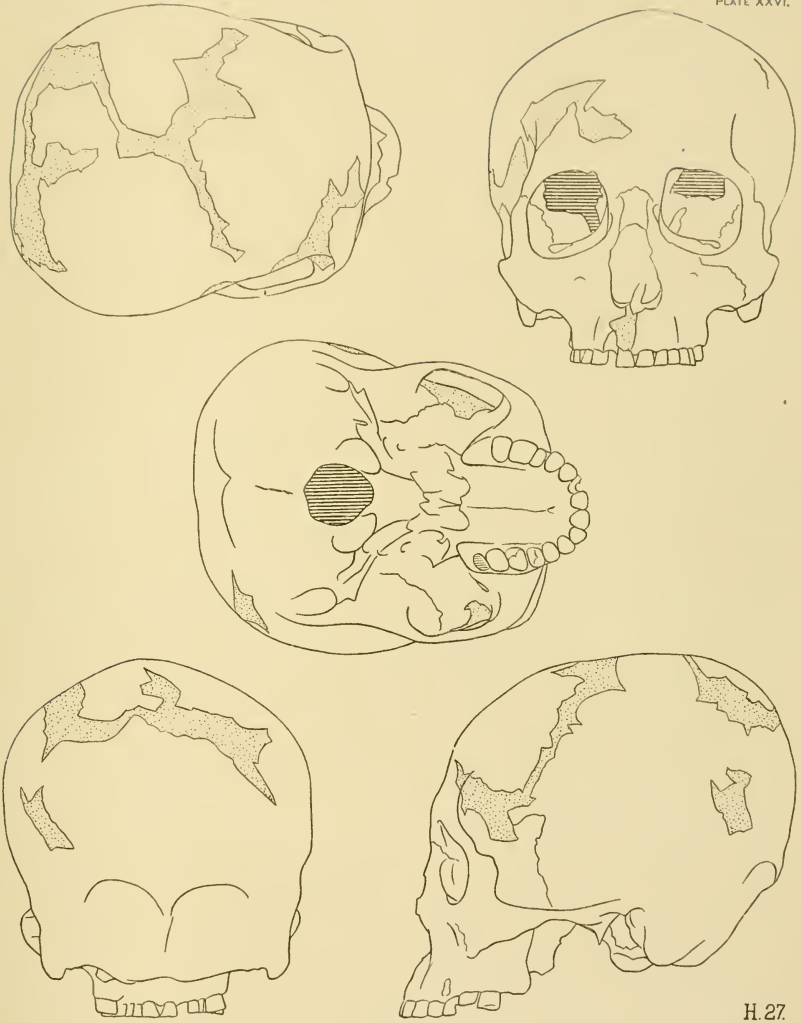

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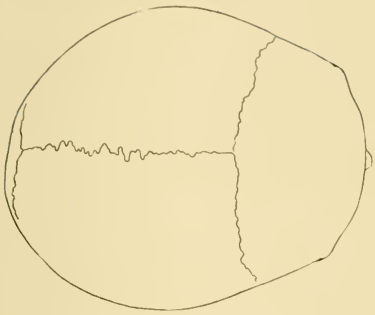

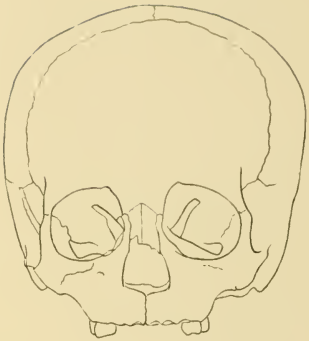

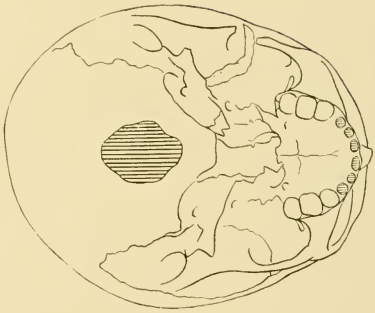

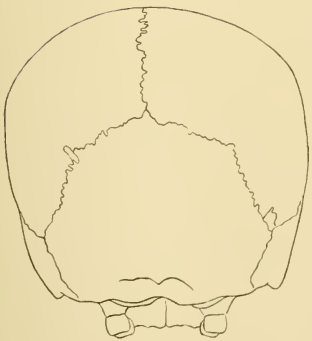

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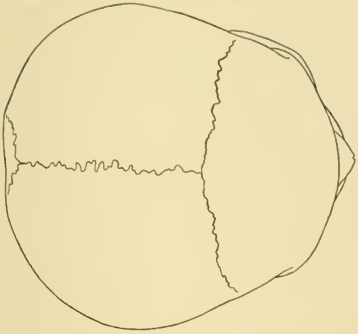

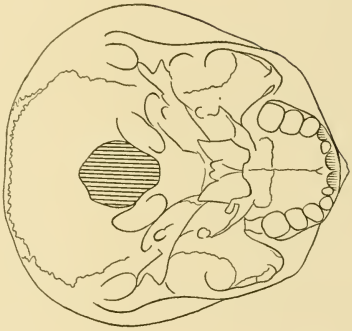

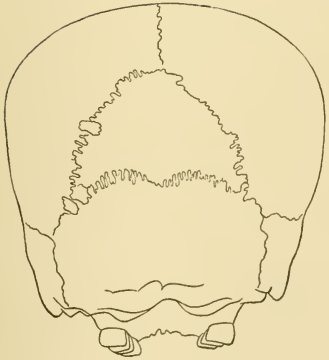

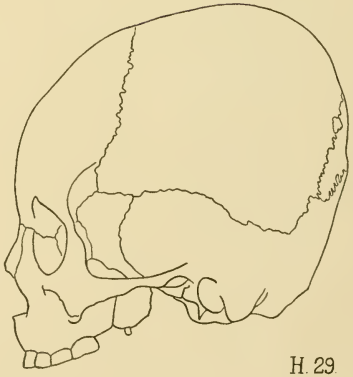

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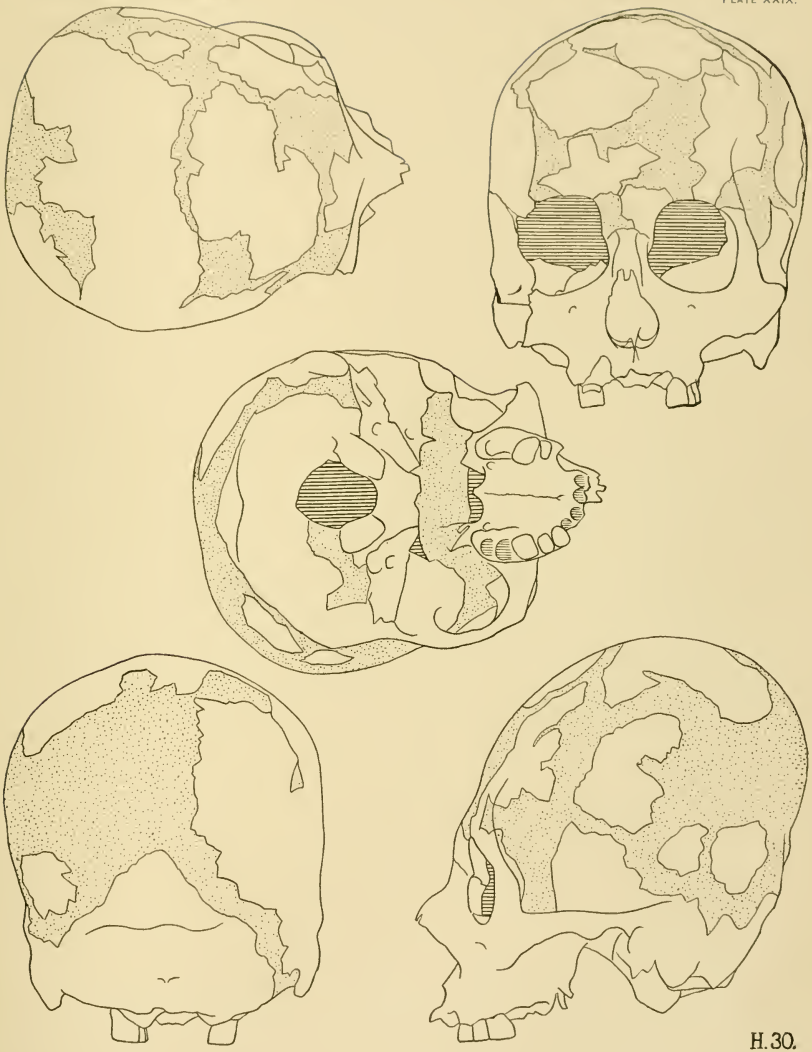

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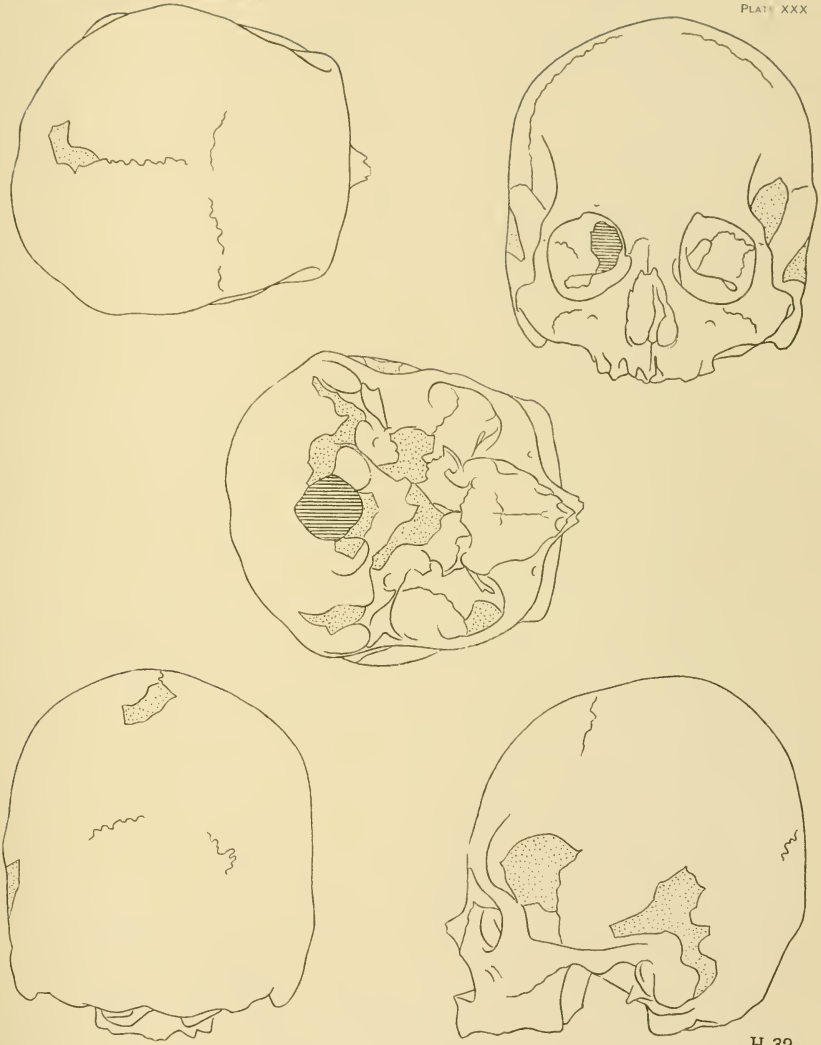

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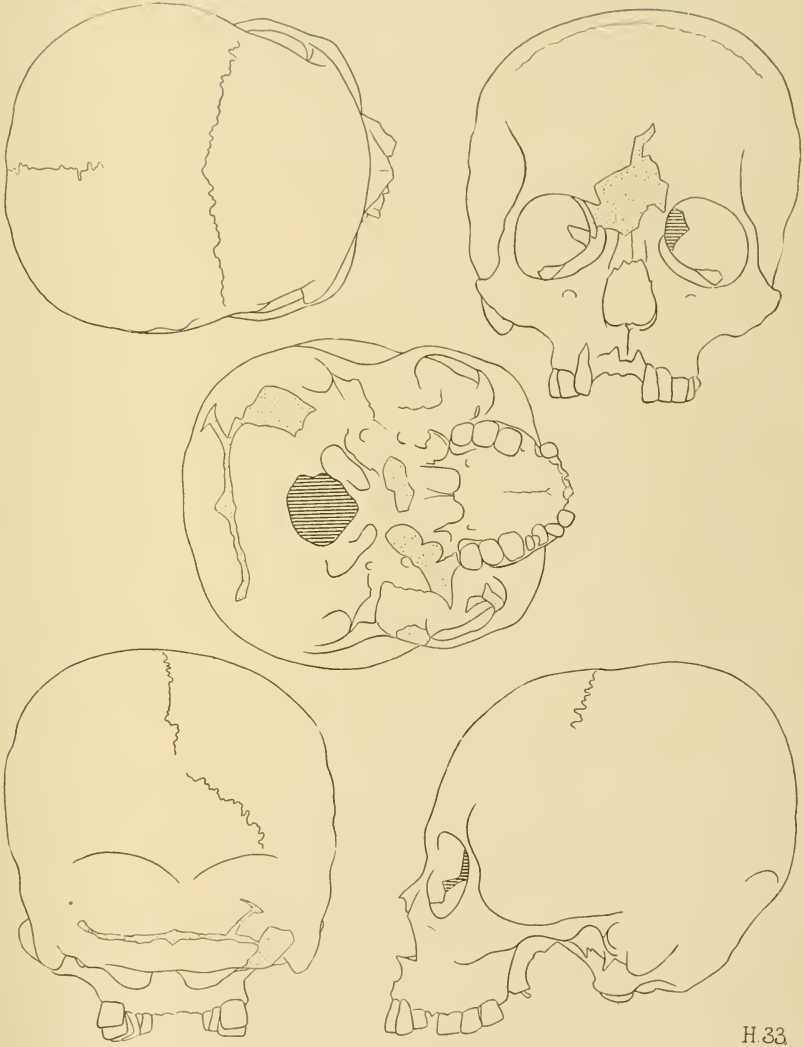

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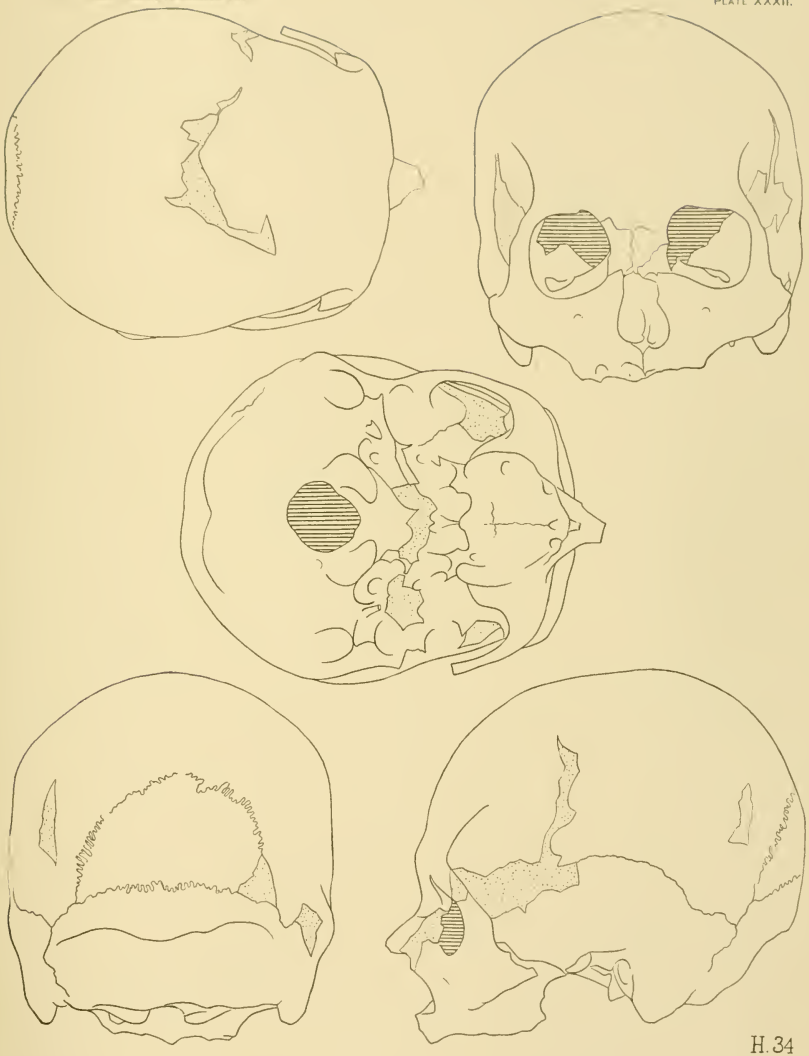

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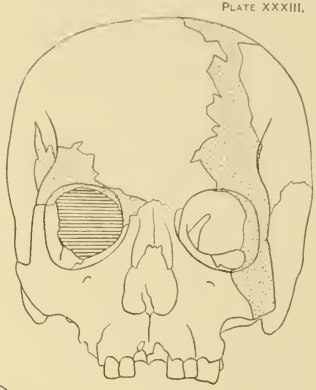

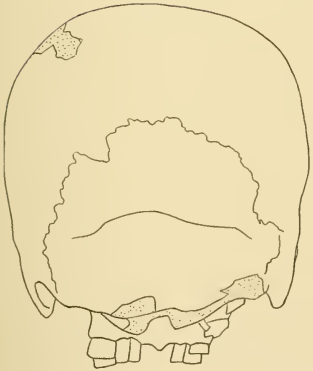

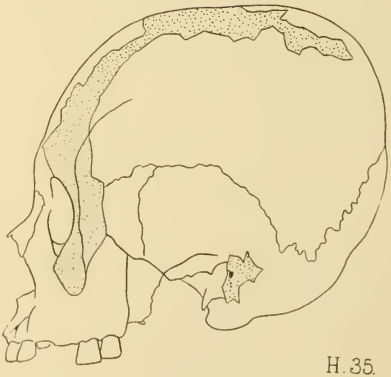

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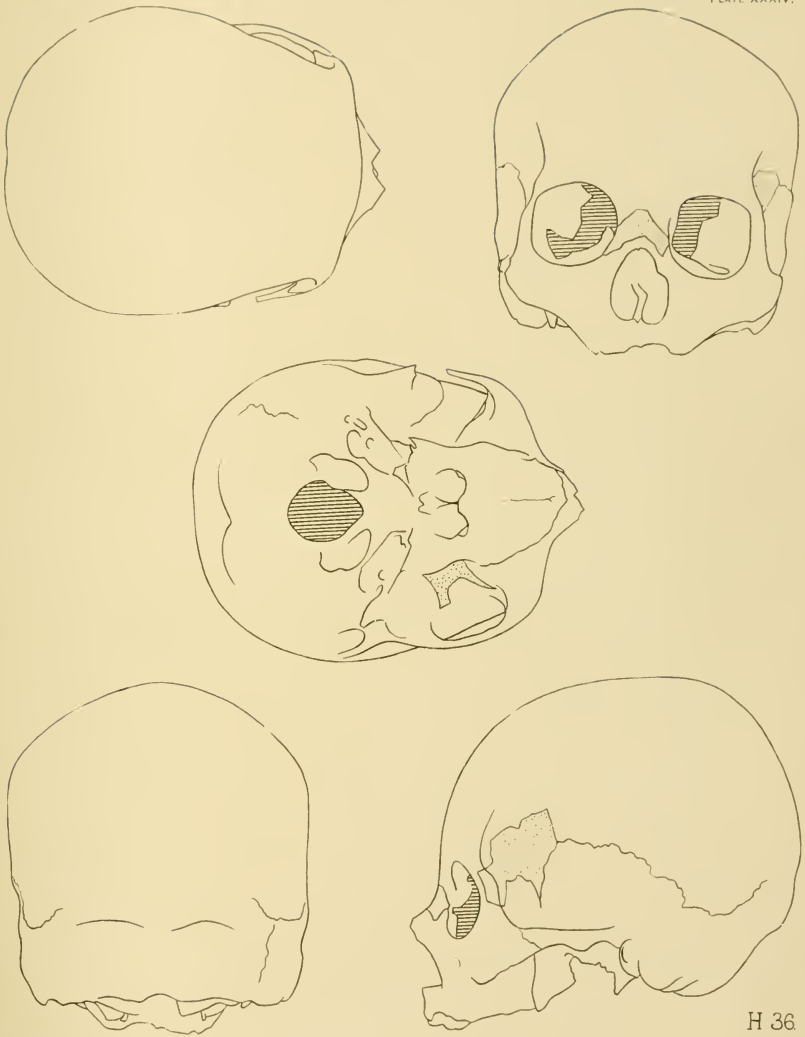

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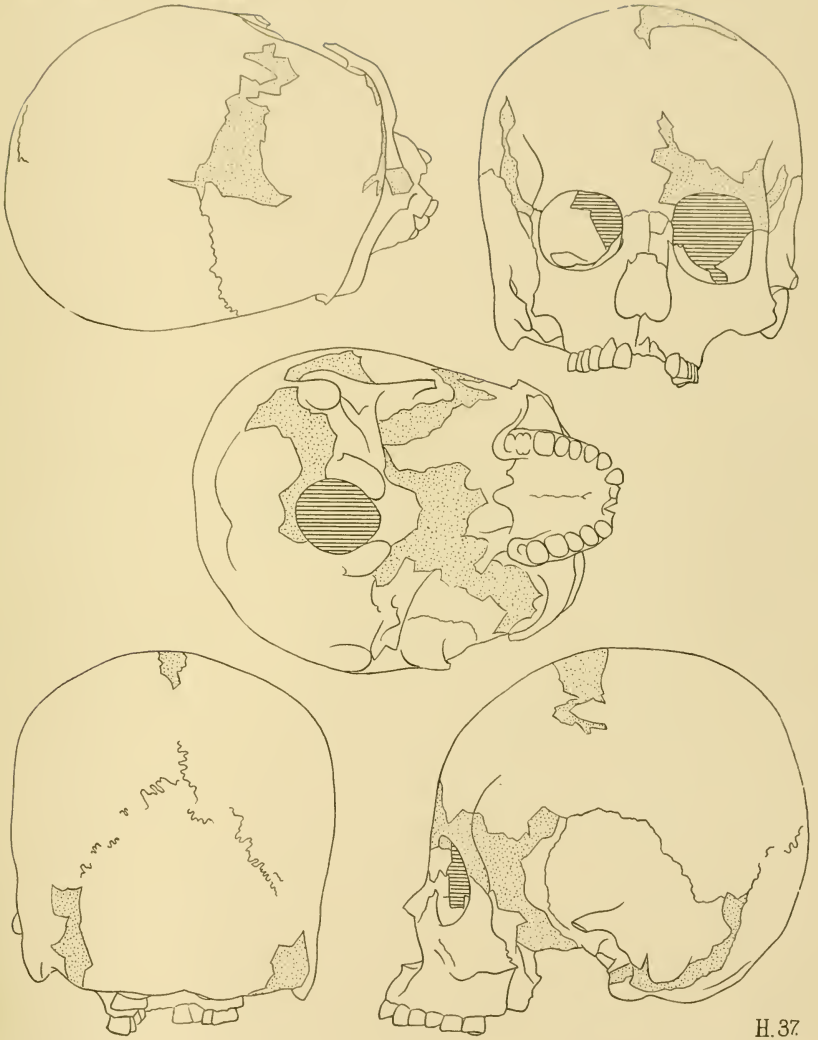

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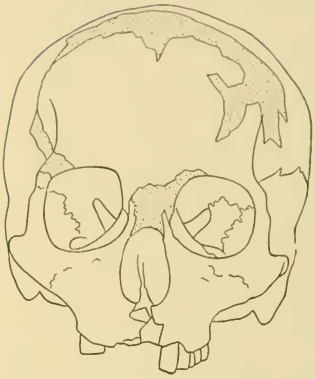

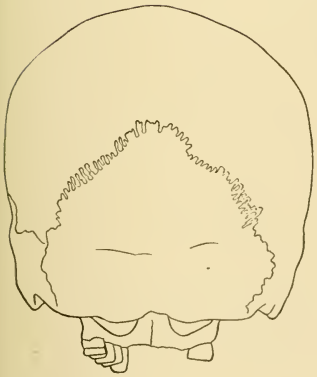

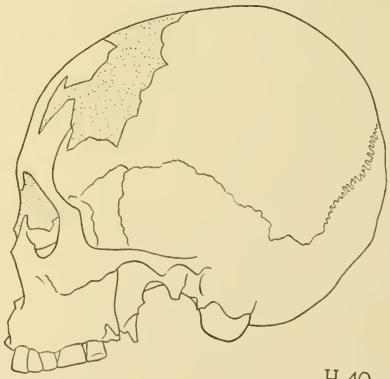

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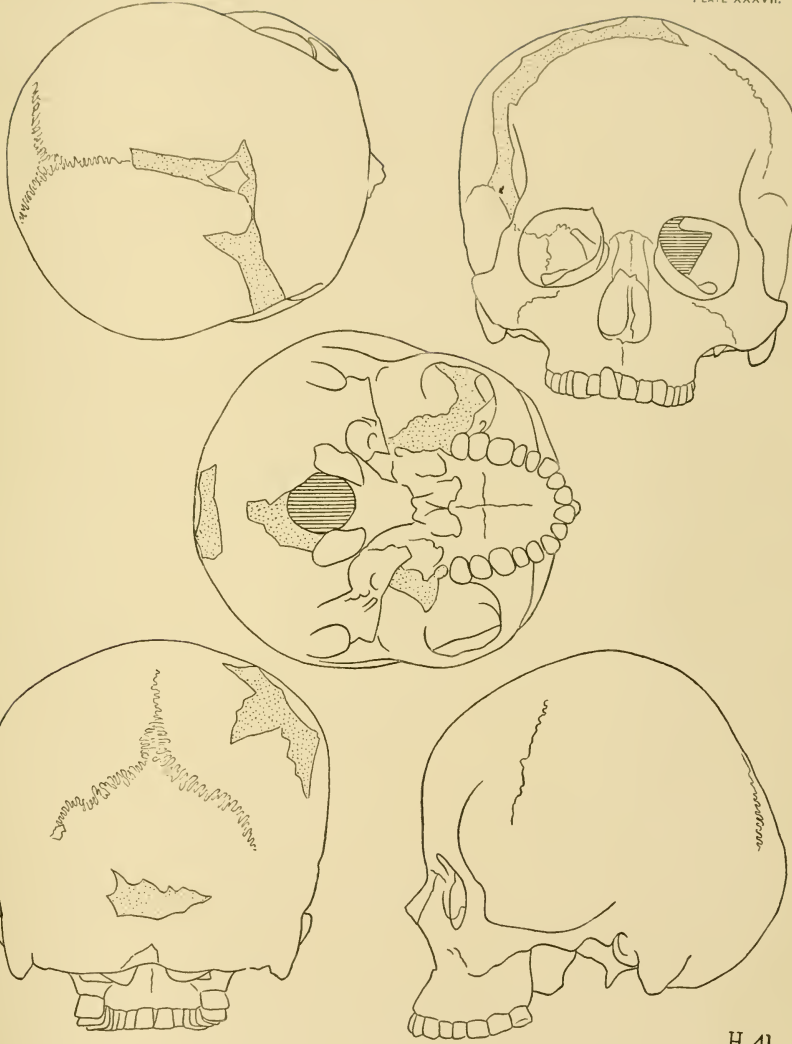

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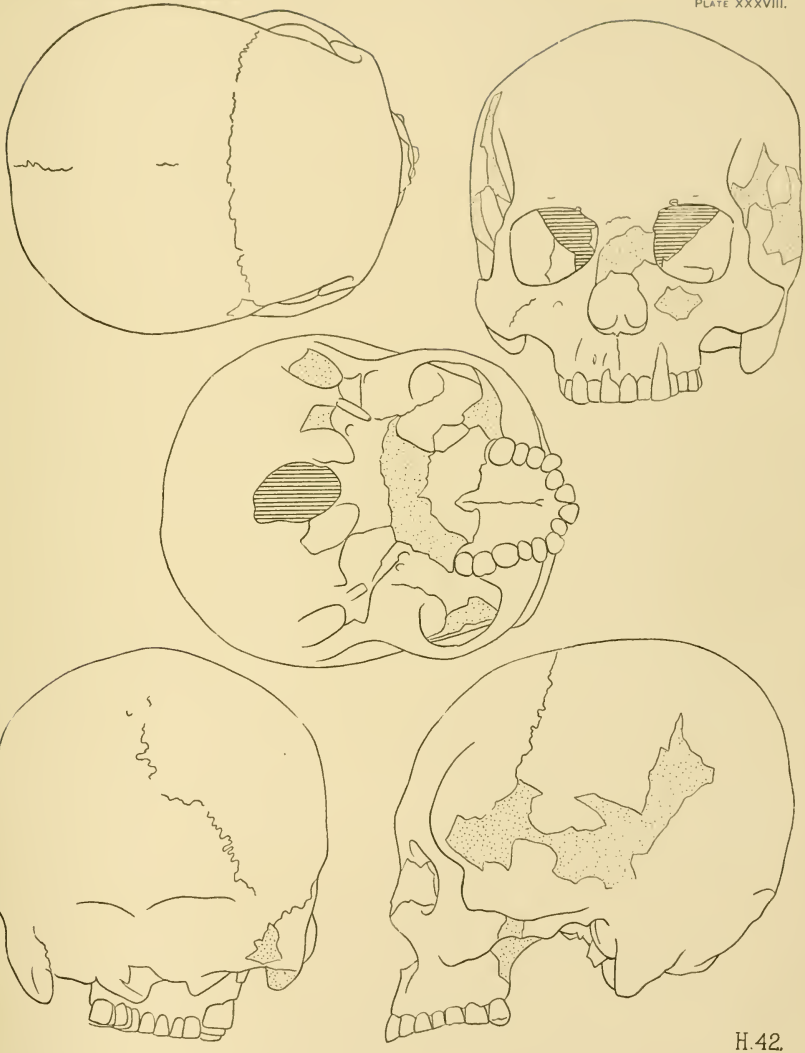

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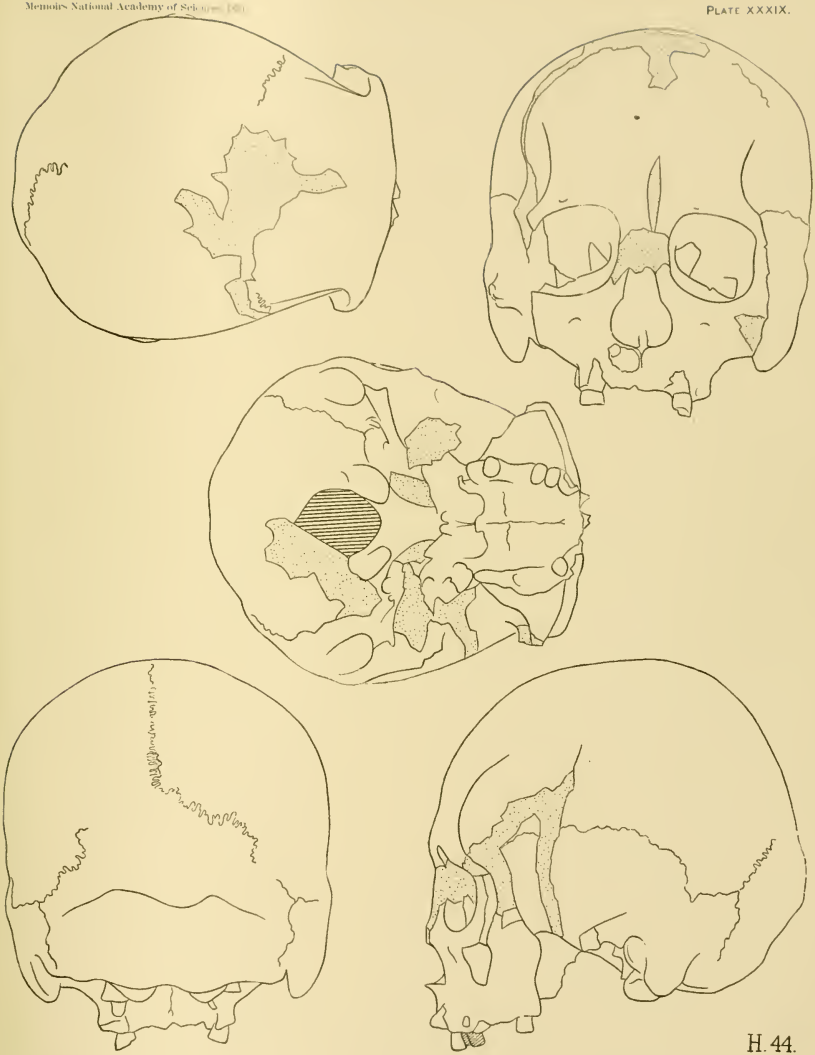

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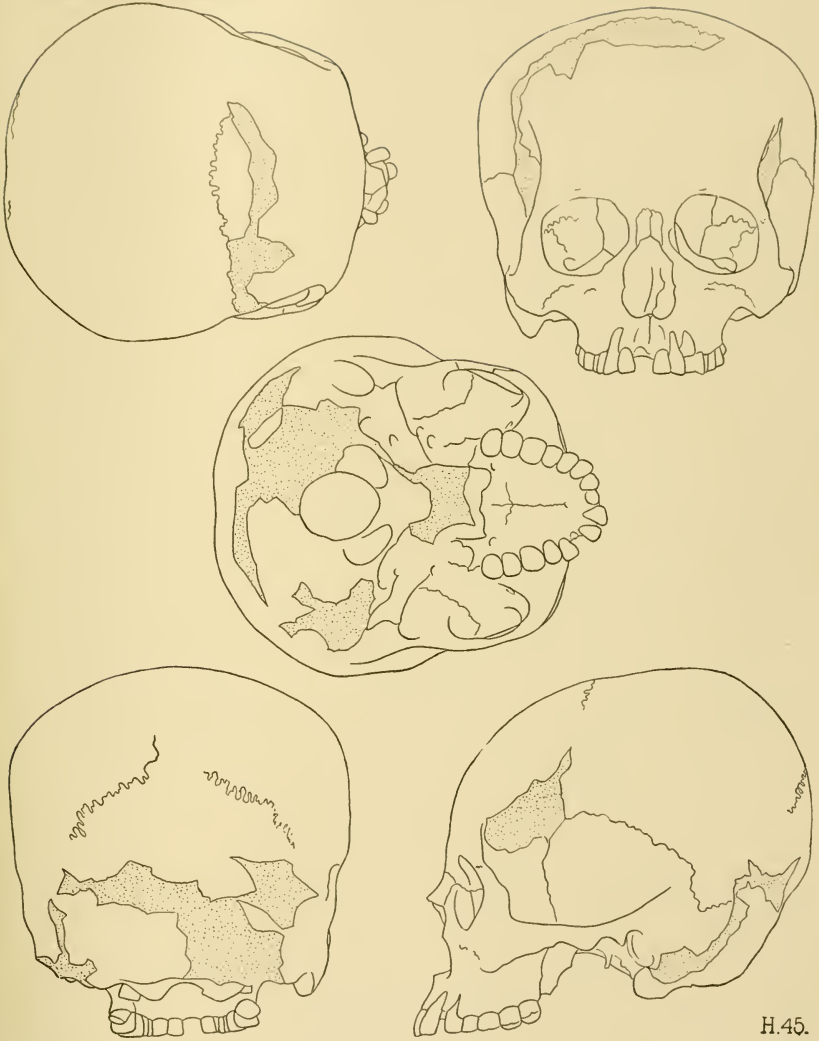

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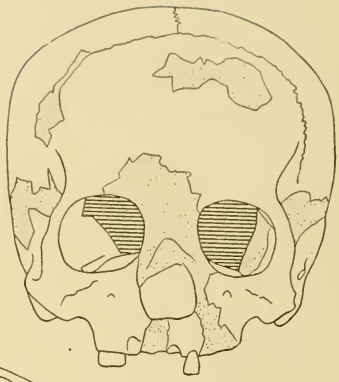

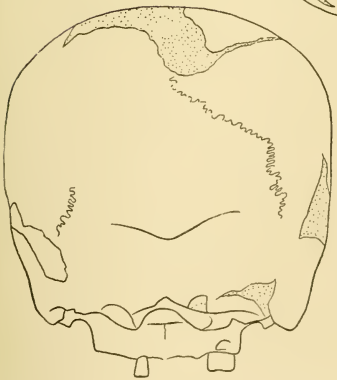

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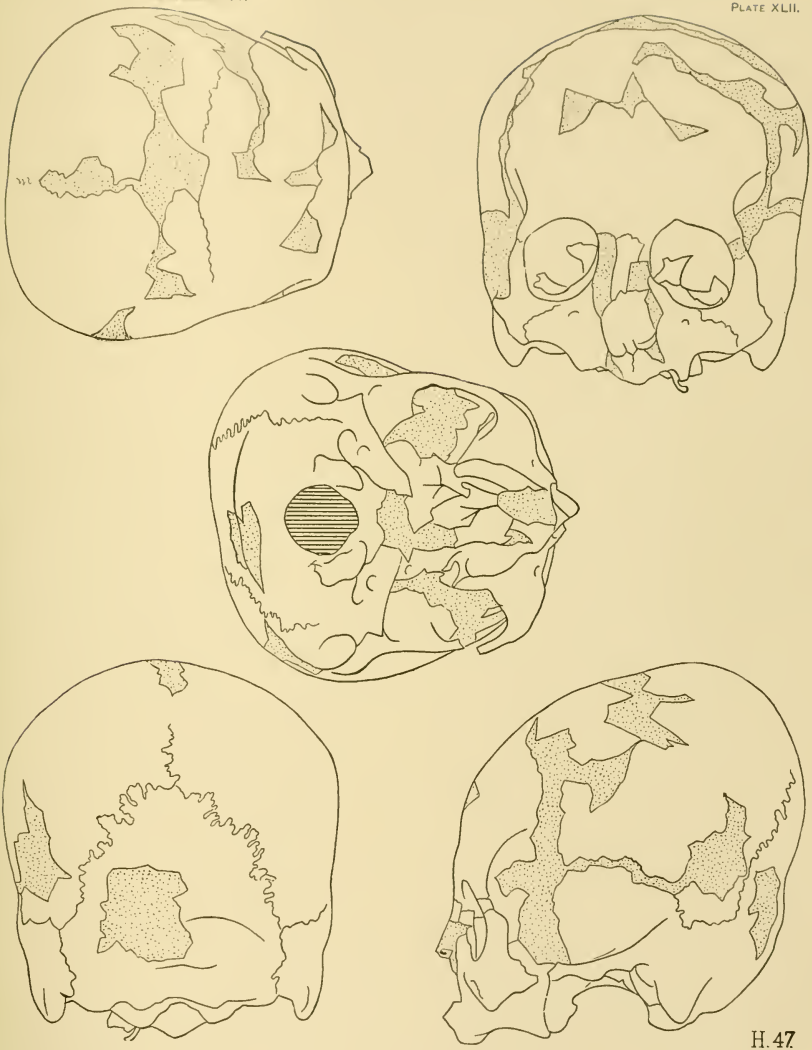

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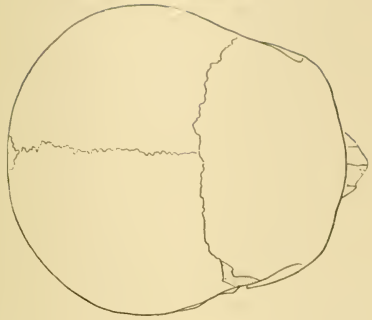

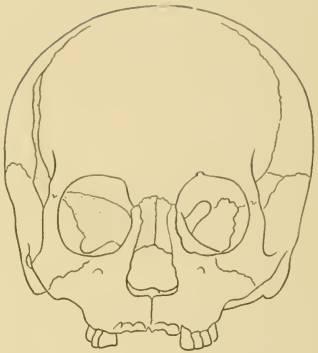

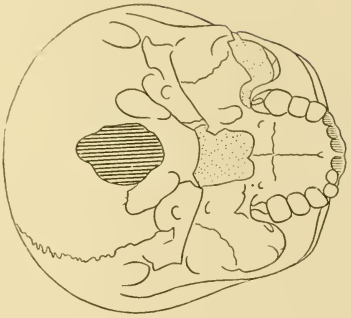

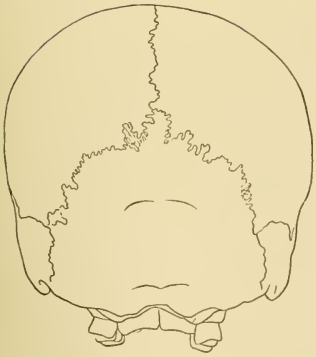

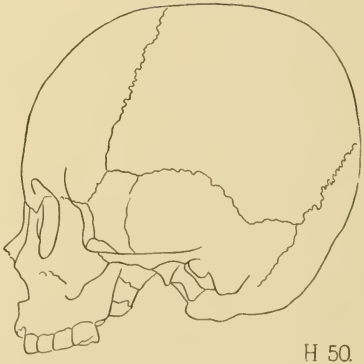

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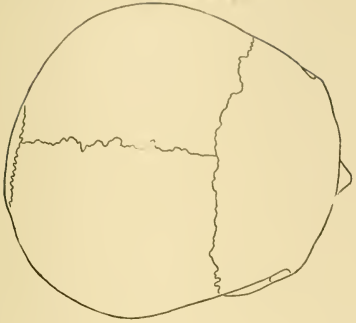

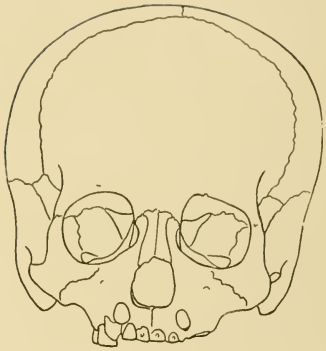

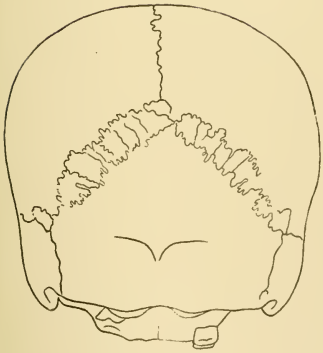

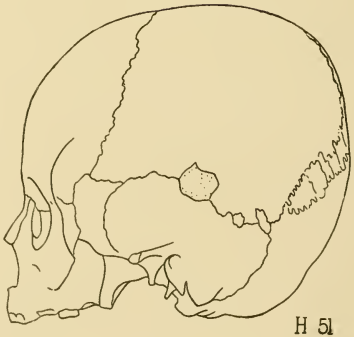

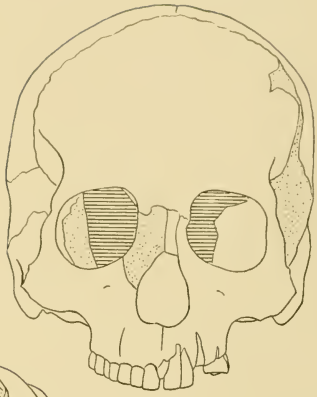

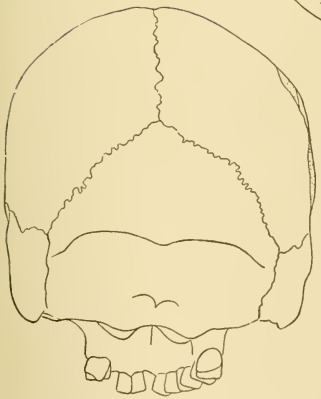

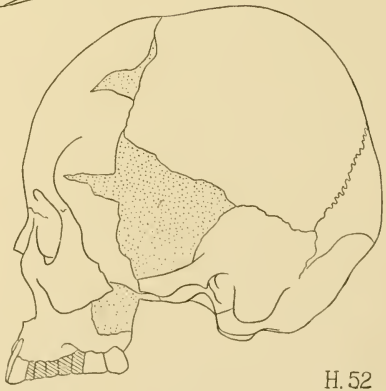

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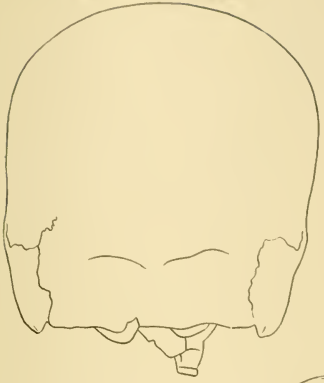

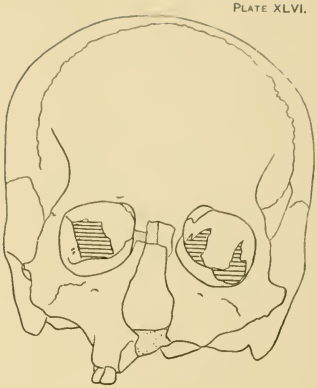

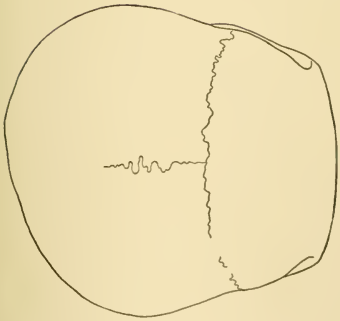

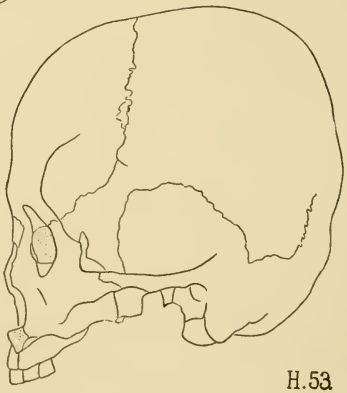

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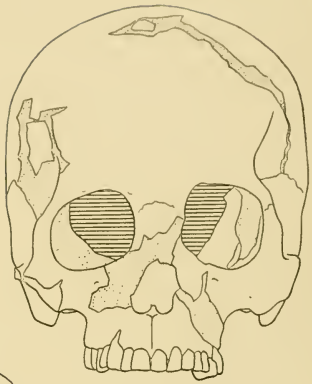

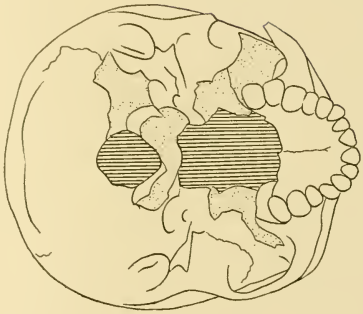

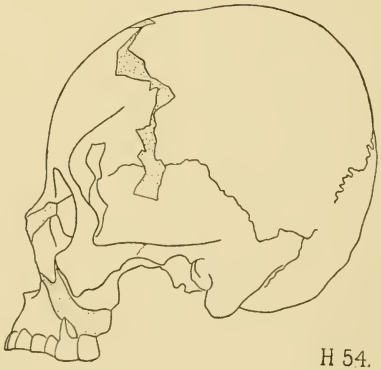

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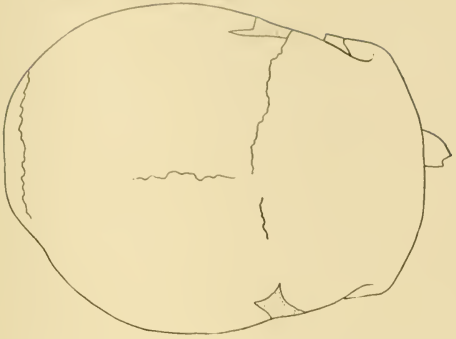

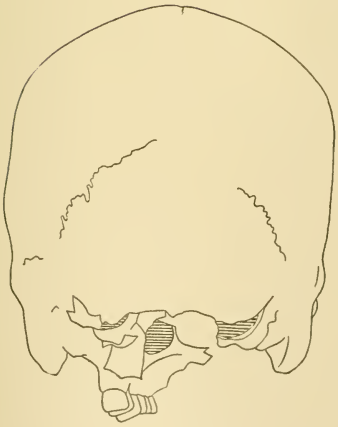

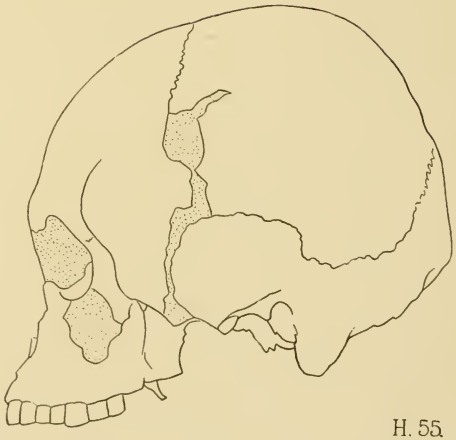

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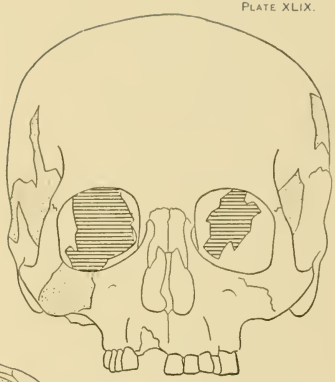
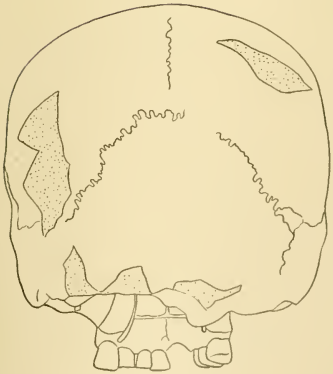
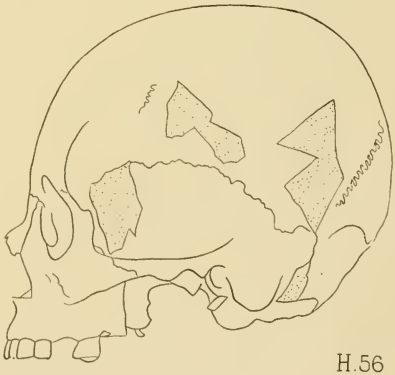
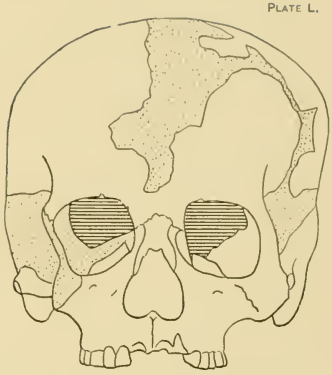
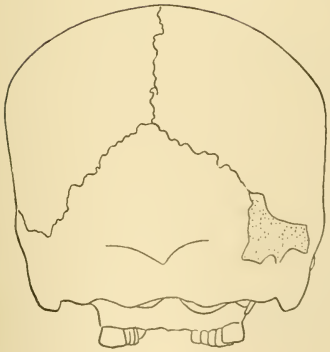


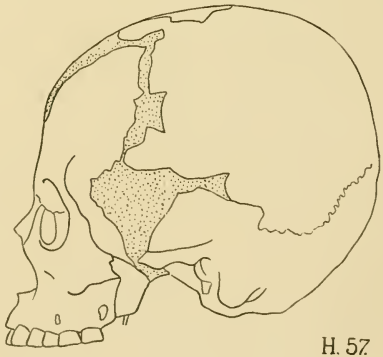




H.56

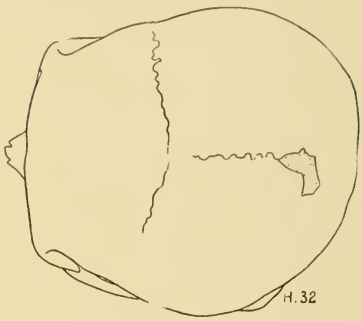






H. 57.

H 23



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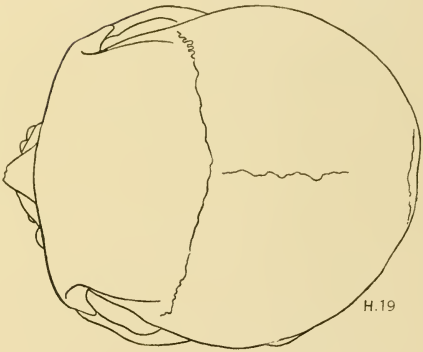

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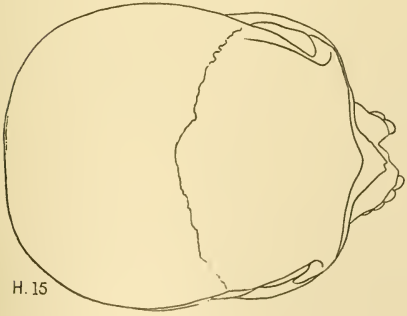

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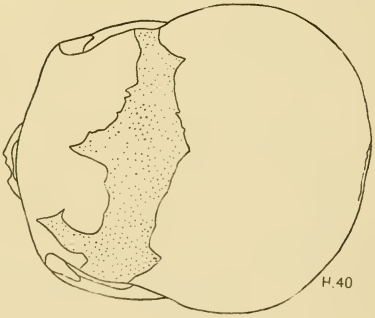

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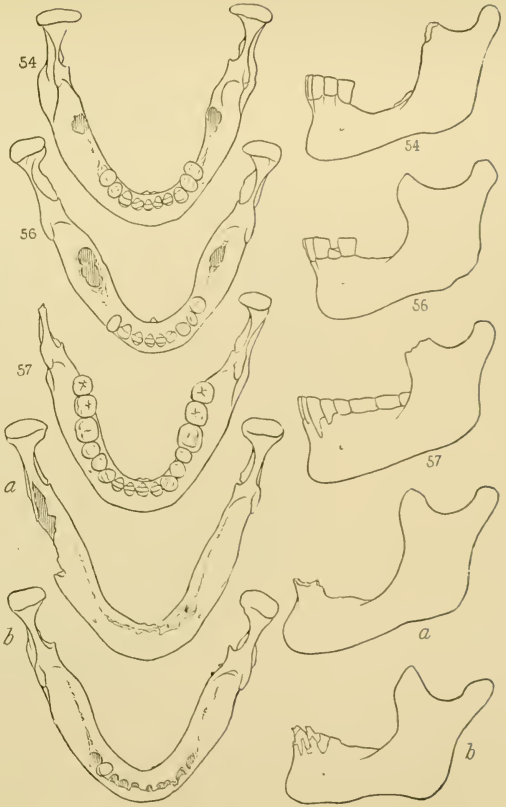
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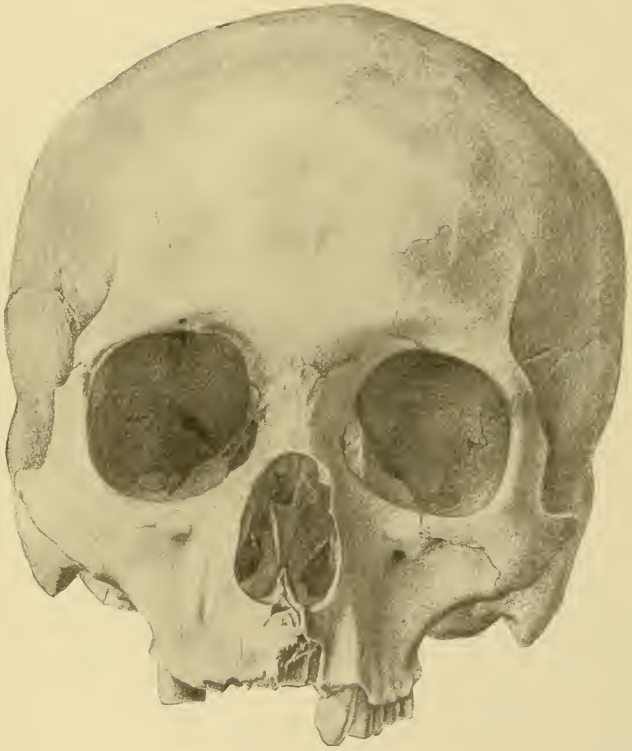

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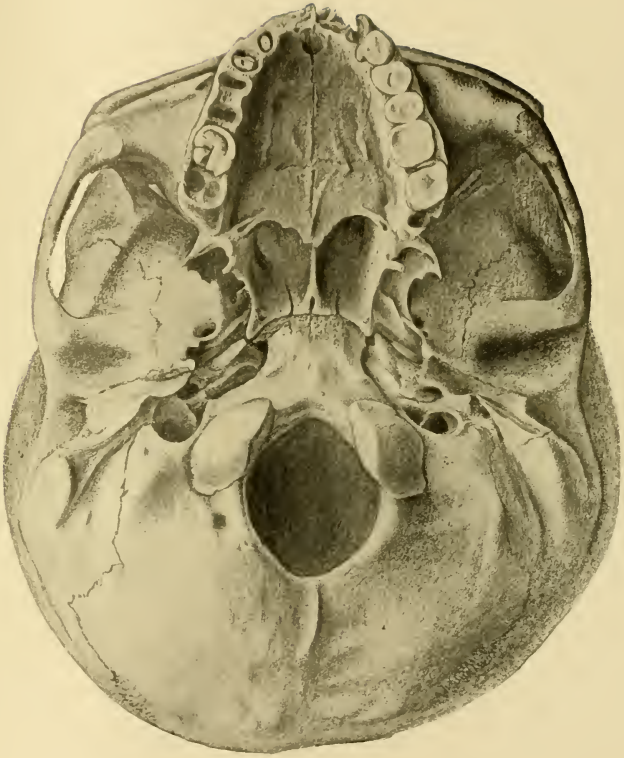

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NATIONAL ACADEMY OF SCIENCES.

VOL. VI.

EIGHTH MEMOIR.

FURTHER STUDIES ON THE BRAIN OF LIMULUS POLYPHEMUS, WITH NOTES ON ITS EMBRYOLOGY.

FURTHER STUDIES ON THE BRAIN OF LIMULUS POLYPHEMUS, WITH NOTES ON ITS EMBRYOLOGY.

By Alpheus S. Packard.

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I. Introduction.

In a former memoir I attempted to describe the brain or præsophageal ganglion of Limulus. The sections were made from brains dissected from the living animal and stained in the manner described by Dietl, being allowed to remain in the osmic acid from twenty to forty hours, while other sections were made by my friend, Mr. Norman N. Mason, from two brains, one of which had been several years in alcohol.

Not at all satisfied with my first essay, not having satisfactorily worked out the topography of the different lobes, I have for several years past, after numerous interruptions, endeavored to get a clear idea of the morphology of the central nervous system both of the adult Limulus and of the embryo, as well as of the freshly hatched larva. Since my first essay appeared two most valuable and exhaustive contributions to our knowledge of the Arthropod brain have been published—the elaborate and richly illustrated memoirs of M. H. Viallanes on the brain of the locust and other insects, and the very sound, detailed, and copiously illustrated work of Dr. Saint Remy on the morphology of the brain of Myriopoda, Arachnida, and Peripatus. In this last work we have for the first time a thorough and exhaustive treatise on the brain of spiders and of the scorpion, and to this work I am indebted for the means of comparison of the brain of Limulus with that of the class of Arachnida.

Several years ago my friend and colleague, Prof. H. C. Bumpus, made a series of sections of the brain of the young Limulus, when about two inches long. The series of transverse sections were stained with osmic acid and were $\frac{1}{50}$ millimeter in thickness, a single brain being cut into 429 slices arranged serially; the brain was, as in the other sections made by him, removed from the living animal and immediately stained and cut. A series of 102 sagittal or longitudinal sections of another brain was stained with alum, carmine, and eosin. The most useful sections of the young animal, however, were the horizontal ones, 76 in number and $\frac{1}{50}$ millimeter in thickness, which were stained with hæmatoxylin and eosin.

A number of these horizontal sections proved useful, as when the animal is young, of the length indicated, the bilateral symmetry of the lobes and ganglion cell masses is more marked than in fully grown specimens.

But my main reliance has been some excellent sections made for me three years ago by Dr. H. C. Bumpus. These were transverse, longitudinal (sagittal), and horizontal sections of the brain, removed from living individuals, about 8 inches in length, exclusive of the caudal spine. The transverse and sagittal sections were stained with hæmatoxylin, the horizontal with carmine. I have also made horizontal sections of the brain of the young Limulus, and especially horizontal, sagittal, and transverse sections of the embryos and larvæ in different stages of development. I have found the horizontal sections to be by far the most useful and the various carmine stains the most desirable, since with this stain the central fibers of the lobes remain white or unstained, while the chromatic cells composing what I have called the "nucleogenous bodies" are colored deep carmine, and thus contrast with the other parts of the brain.

In order to comprehend the topography of the brain, while my main reliance has been a study of the horizontal sections, I found it useful to draw models of different sections on cardboard and to mount them on a long insect pin. By the use of this simple device I could obtain a tolerably clear idea of the relations between the lateral and median optic lobes and the cerebral lobes, relations by no means so easily understood as those prevailing in the brains of Crustacea and insects.

Also, at the kind suggestion of Dr. Bumpus, I made a wax model of the brain, and for aid in preparing the sheets of beeswax and for other suggestions I am also indebted to Dr. Bumpus. I made a model from the horizontal, sagittal, and transverse sections; but, owing to the difficulty of painting or otherwise marking the exact limits of the different very irregularly shaped lobes on the sheets of wax, I have not had specially good success in locating on the wax the different lobes and roots of the nerves proceeding from them. The portion of the clearly and distinctly stained nucleogenous bodies can, however, readily be indicated, and as concerns the relations of these masses to each other and to the brain in general the wax models have been quite serviceable. Such models would undoubtedly prove useful in dealing with the brains of insects, Crustacea, and Arachnida, as well as Myriopoda.

II. General Anatomy of the Brain of Limulus.

The nervous system of the Limulus was first described and figured by Van der Hoeven in 1838, the subject of his investigation being *Limulus moluccanus* Latreille, represented by two specimens from the Dutch possessions in the East Indian archipelago. That of the American species, *Limulus polyphemus* Latr., has been described and figured by Sir Richard Owen and afterwards more accurately and with many details by M. A. Milne-Edwards.* It is noticeable that the brain and œsophageal ring, with their nerves, are identical in shape in the two species, there being apparently but very little difference, externally, or internally, in the species of Limulus, both living and extinct.

The central nervous system consists of an œsophageal ring formed by the consolidation on each side of the œsophagus of the six ganglia innervating the six pairs of cephalic appendages. The ring is closed in front by the supra-œsophageal, or to speak more correctly, the pre-œsophageal ganglia or brain; the brain is the partial homologue of the supra-œsophageal ganglia of other Arthropoda.

It will be remembered that in other arthropods the brain is situated in the upper part of the head, in a plane somewhat different in direction from that of the rest of the ganglionic cord. In the Arachnida the supra-œsophageal ganglion also is in a different plane from that of the œsophageal mass, forming a small, more or less bilobed subspherical mass resting directly over and upon the front part of the œsophageal nerve-mass or œsophageal ring. In Limulus, however, as seen by Fig. 1 (in the text), the flattened subovate brain is situated directly in front of and in the same plane as the œsophageal ring and also the abdominal portion of the central nervous system.

Hence the position of the brain is pre-œsophageal rather than supra-œsophageal. The brain

* For references to the works of this and of other authors see the bibliography at the end of this article.

is separated from the œsophageal ring by a slight but yet distinct constriction seen both above and beneath, the constriction on the upper or dorsal side passing just behind the lateral eye lobes, viz., those sending nerves to the large lateral compound eyes. It is broader at the base than it is thick, and narrow in front, seen from above, so that it is about a fourth narrower in front (in front of the origin of the lateral eye nerves) than at the base or posterior end.

The ventral or under side is quite regularly convex and fuller and rounder than above; the convexity or fullness is greater in the center and drops or extends down considerably below the origin of the nerves of the first pair of appendages, this being the portion below the central lobes and which is filled with the ruffllelike masses of small, ganglionic or chromatic cells.

The brain of a Limulus about 10 inches long, exclusive of the caudal spine, is about 6 mm. in diameter; it is conico-spheroidal, broad and flattened from above, and on the under side full

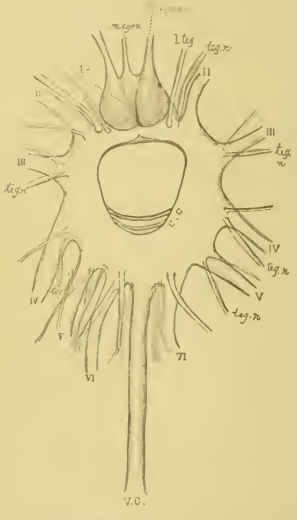

FIG. I. Brain and œsophageal ring of Limulus, seen from above; *br.*, brain; *cc.*, commissures behind the œsophagus; *m. eyé n.*, median-eye nerve; *lat. eye n.* lateral-eye nerve; I-VI, nerves to the six pairs of cephalothoracic appendages or legs. *v. c.* ventral cord; *l. teg.*, lower tegumental nerve; *teg. n.* other tegumental nerves.

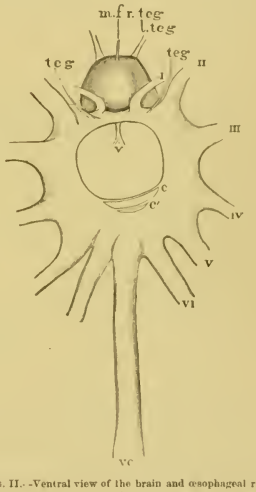

FIG. II.—Ventral view of the brain and œsophageal ring of Limulus. *m. fr. teg.*, medio-frontal tegumental nerve; *b. teg. n.*, lower tegumental nerve or nerve to the sensorial pit. Author del.

and rounded; on the upper side is a broad, shallow, median furrow, indicating that it is double. In the young Limulus, with a body about 2 inches long, exclusive of the caudal spine, the brain is longer, narrower, and less spherical.

Three pairs of nerves and a median unpaired one (the ocellar) arise from the upper third of the anterior face of the brain. The two lateral-eye nerves are the largest, arising very near the upper side of the brain, one on each side of the median furrow, so that the second and third sections made by the microtome pass through them. Next below (from above downwards) is the origin of the single nerve sent to the two ocelli. We have not traced this nerve as far as the ocelli, but Milne-Edwards states that near the ocelli it divides into two branches. On each side

of the ocellar nerve, and in nearly the same plane, arise two tegumental nerves, and directly below them a second pair of longer nerves (fronto-inferior tegumental of Milne-Edwards) descend ventrally. No nerves arise from the inferior half or two-thirds of the brain, which is smooth and rounded, with no indications of a median furrow. There is also an unpaired mediofrontal nerve.

It will then be seen that, as stated by A. Milne-Edwards, there are no antennal nerves, such as usually exist in anthropods with the exception of the Arachnida. This we have proved in the same manner as Milne-Edwards (though at the time ignorant that he had pursued the same method), by laying open with fine scissors the envelope (arterial or perineurial) which reaches to the posterior end of the brain and seeing that the fibers of the nerves sent to the first pair of appendages originate quite independently of the brain itself. Moreover, after making sections of several brains, it is easy to see that only the commissures connecting the brain with the œsophageal ring are present, the nerves to the first pair of appendages not arising from the brain itself, but from the anterior and outer part of each side of the œsophageal ring, *i. e.*, where the ring joins the brain. It is to be observed that the nerves of the first pair of appendages arise in the same plane as those of the second and succeeding pairs. The commissures (connectives) are very short in the larva and obsolete in the adult.

III. THE MORPHOLOGY OF THE BRAIN OF LIMULUS SEEN EXTERNALLY AS COMPARED WITH THAT OF ARACHNIDA.

The brain of Limulus is a very primitive one, more so than that of Arachnida, and should be in this respect compared with that of the crustacean Branchipus. It is an *archicerebrum*,* to use

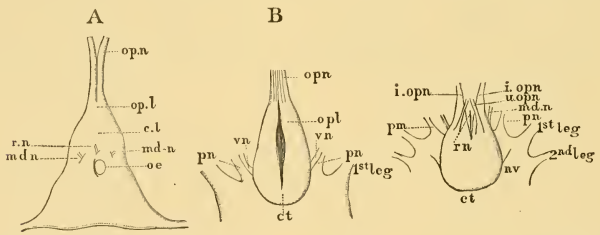

FIG. III.—A, brain of Phalangium; B, brain of Lycosa; C, brain of Epeira; *op. n*, optic nerve; *op. l*, optic lobe; *c. l* (and *ct*) cerebral lobe; *md. n*, mandibular nerve; *r. n*, rostral nerve; *oe*, œsophageal ring; *vn* (and *nv*), visceral nerve; *pn* (and *pm*) pedipalpal nerve; *i. opn*, lower optic nerve; *u. opn*, upper optic nerve.—After St. Remy.

the term proposed by Lankester. It sends nerves to the eyes alone and none to the appendages. As we shall see in the course of our essay it is composed of optic lobes alone, together with the cerebral lobes and their nucleogenous or mushroom bodies. This primitive condition places it only slightly above the grade of that of Peripatus.

It may be observed that even within the limits of the Crustacea there is a great range of variation in the constitution of the supra-œsophageal ganglion. The simplest condition, that in which the Crustacean brain is almost directly homologous with that of annelids, is to be found in the brain of the phyllopods (Limnetidæ and Branchipodidæ), where the diminutive brain is composed of the optic and cerebral ganglia alone, the brain of these forms being the most primitive to be found in arthropods. In these brains no antennal ganglia occur; they are situated behind the brain. The next step is seen in Apus, whose brain, contrary to Lankester's assumption, has been

* The terms syncerebrum and archicerebrum appear to us to apply to very different kinds of brain. The archicerebrum of Branchipus, for example, is a very different organ from that of Limulus, both histologically and morphologically. That of Branchipus is simpler and more wormlike than that of Limulus.

proved by Pelseneer to contain the antennal ganglia, though the nerves branch off at a considerable distance from the brain, on the side of the œsophagus. A step higher is seen in the brain of isopods, where, as we have described and figured * the first and second antennal ganglia of Asellus are not closely coalesced and consolidated with the optic and cerebral lobes, but are separate from the brain and situated below and posterior to it, though in front of the œsophagus. The most complex type of crustacean brain is that of the highly specialized Decapoda.

The brain of adult insects is on the same high plane as that of decapod crustacea, the optic and antennal lobes being invariably coalesced with the cerebral, the whole mass being separated from the infra-œsophageal ganglion, and so it is with the brain of myriopods.

The Arachnidan brain is very distinct in its external appearance from that of insects or crustacea.

Prof. Pattent has given us what is apparently a clear and accurate figure on an enlarged scale of the scorpion's central nervous system, which we take the liberty to copy, with a change in position and consequent change in the lettering.

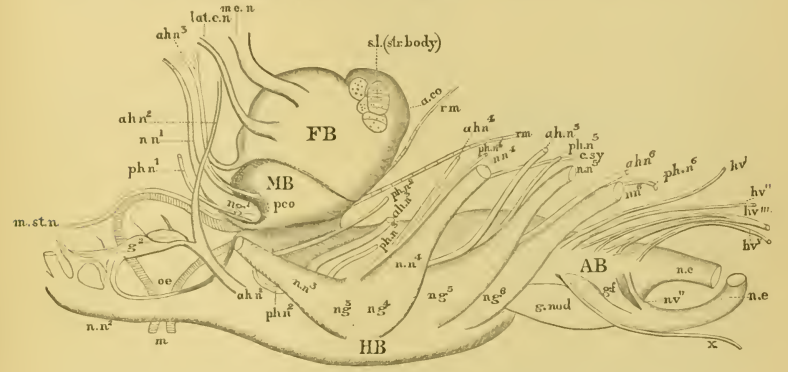

FIG. IV.—Brain of adult scorpion, constructed by means of sections and dissections. A. B., accessory brain; H. B., hind brain; M. B., mid brain. F. B., fore brain; *a. co.*, anterior commissures; *a. h. n.*¹⁻⁶, anterior hæmal nerves of the thoracic neuromeres; *c. ay.* cranial sympathetic (*b*); g^2, large ganglion derived from the segmental and coxal sense organs, and giving off many branches to the scattered sense organs in skin of chelæ; *g. f.*, ganglion fusiforme; *g. nod.*, ganglion nodosum or *g. striatum*; *h. n. s.*, a very delicate root, probably representing the hæmal nerve of the third fore-brain neuromere, partially fused with the hæmal nerve of the cheliceral segment; *h. v.* and *h. v.*', the independent anterior and posterior nerves of the first vagus neuromere; *h. v.*¹ᵃ and *h. v.*¹ᵇ, the four partially fused hæmal nerves of the second and third vagus neuromeres; *lat. e. n.*, lateral-eye nerve; *m*, mouth; *me. n.*, median-eye nerve, *m. st. n.*, median stomodæal rostral nerve; *n. e.*, comb or pectinal nerve; *ng.*¹⁻⁶, neural ganglia at the base of the neural nerves; *n. n.*¹⁻⁶, neural nerves of the thoracic segments; *h. v.*¹⁻⁴, roots of the neural vagus nerves; *ph. n.*¹⁻⁶, posterior hæmal nerves of thethorax. *p. co.*, posterior brain commissure. *s. l.* (str. body), semilunar lobe or first brain segment. *r. m.*, retractor muscles to œsophagus.—After Patten.

Prof. Patten incorrectly applies the term "brain" to the entire central nervous system, only excepting the abdominal ganglia, dividing the brain and œsophageal ring or mass into three divisions, viz, the fore, mid, and hind brain, as indicated in his figure. But restricting the term brain to the supra-œsophageal ganglionic mass, it will be seen that the ganglia which innervate the first pair of appendages, though separate in the embryo, are in the adult scorpion closely united with the brain, though there is a slight constriction between the two portions of the brain, viz, between the "mid brain" (or rostro-mandibular ganglion of St. Remy) and the "fore brain."

It is desirable also, for the sake of clearness, not to consider the "hind brain" as a part of the brain, since it is a post-œsophageal mass, innervating the cephalic and thoracic appendages,

* Structure of the brain of sessile-eyed Crustacea.

† Quart. Journ. Micr. Sc., 317, 1890.

viz, the mouth-parts and the four pairs of legs. No author, so far as we are aware, but Patten, has extended the term brain to include the post-œsophageal mass, and he apparently does this in order to carry out his fancied homology of the scorpion's central nervous system with the brain and spinal cord of vertebrates.

St. Remy has in a masterly way described the brain of the higher Arachnida (Phalangidæ, Spiders, and Scorpions), restricting the term brain to two regions, the first of which he calls, after Schimkewitsch, the "optic ganglion," which furnishes the optic nerves only. (St. Remy's term "optic ganglion," which is not a happy one, since the same name has been used by nearly all authors for the optic ganglion of insects and decapod crustacea, viz, the mass of cells situated between the optic lobes and the optic nerves, should be designated by the general name supra-œsophageal ganglion.*)

According to St. Remy, this region comprises "three perfectly characterized parts in all the types which we have studied, the optic lobes, the posterior stratified organ, and the cerebral lobes." The second region of the brain, which St. Remy† designates the rostro-mandibular ganglion, is the midbrain of Patten. This portion, then, innervates the first pair of appendages of Arachnida and also the rostrum, which St. Remy regards as the homologue of the labrum of insects and crustaceans.

We hold the view that the brain, or pre-œsophageal ganglionic mass, or prostomial nervous centers of Limulus, is not the homologue of the brain of Arachnida, but only represents the first region of it, the optic ganglion of Schimkewitsch and of St. Remy, and the forebrain of Patten. It lacks the rostro-mandibular ganglion of the arachnid brain, this ganglionic mass being fused with the œsophageal ring and more intimately united with it than with the brain. Thus the brain of Limulus is simpler, more primitive, and, in this respect, more like that of Peripatus and Annelids than is that of Arachnida.

We hope to show that this can be proved not only by gross dissection of the adult, but by the facts and figures which we give in this paper.

For the adult brain can be readily dissected from the œsophageal ring without cutting into the brain, and as will be seen in my figures of the horizontal sections of the brain (see especially Pl. VI, Fig. 1, and Pl. V, Figs. 20–22, *g. app'*), the mass of ganglionic cells supplying the nerves to the first pair of appendages are behind and ontside of the brain proper.‡ The division can also be seen in the entire brain, and also in Milne-Edwards figures. Moreover, the embryonic and larval conditions prove that the rostro-mandibular region in Limulus belongs with the œsophageal ring.

Viallanes, in his admirable memoir on the brain of the locust (Annales Sc. Nat., p. 1, 1887), has proposed a new classification of the parts of the brain.

He divides the brain of insects and of crustacea into three segments, *i. e.*, the *protocerebrum* (brain of the first zoönite); the *deutocerebrum* (brain of the second zoönite), and the *tritocerebrum* (brain of the third zoönite).

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*The term supra-œsophageal ganglion is an inexact one, as in reality it is composed of from two to four pairs of ganglia, which are separate in the embryo, becoming consolidated in the adult. The term supra-œsophageal ganglionic mass, or prostomial ganglionic mass, would be more exact, unless a briefer single word could be suggested; meanwhile the term *brain* is sufficient for ordinary use, only bearing in mind that this organ varies in the number of primitive lobes in different classes of Arthropoda.

†La seconde région du cerveau, que nous avons désignée sous le nom de *ganglion rostro-mandibulaire*, a une constitution beaucoup plus simple et, par suite, beaucoup plus semblable dans tout le groupe. Elle se compose d'une masse nerveuse, traversée par le tube digestif, dont la portion sus-œsophagienne se divise en avant en trois lobes, un impair, très petit, d'où part sur la ligne médiane le nerf du rostre, et deux autres plus volumineux, disposés latéralement, qui donnent naissance aux nerfs des chélicères. Ceux-ci forment une seule paire chez les Phalangides et chez les Aranéides où nous les avons vus se diviser bientôt en deux branches; il y en a deux paires chez les Scorpionides, les deux nerfs de chaque côté correspondant vraisemblablement aux deux branches de division du tronc unique des Aranéides. Le ganglion rostro-mandibulaire donne naissance, dans ce dernier groupe, à une paire de nerfs viscéraux. (P. 230.)

‡Different anatomists have taken different views of this subject. Dohrn remarks: "Bei Limulus aber wird nur das vorderste Paar der Gliedmassen von dem oberen Schlund-ganglion versagt; die übrigen empfangen ihre Nerven aus der Bauchganglienkette," p. 585. On the other hand Lankester remarks: "In the first place the brain and œsophageal collar of Scorpio are more intimately fused with one another than are the corresponding parts of Limulus," and adds further on: "From the collar, then, in Scorpio as in Limulus, the nerves to all six of the pediform appendages take their origin." ("Limulus an Arachnid," pp. 9 and 10).

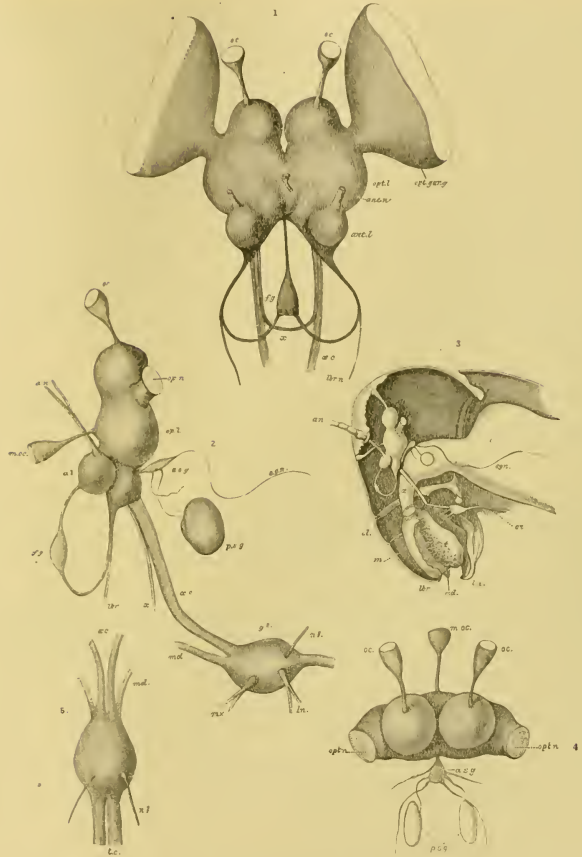

FIG. V.—*Brain of the locust.* 1. Front view of the brain of *Caloptenus femur-rubrum*: *opt. gang.*, optic ganglion; *oc.*, ocelli and nerves leading to them from the two hemispheres, each ocellar nerve arising from the region containing the calices; *m. oc.*, median ocellar nerve; *opt. l.*, optic lobe sending off the optic nerve to the optic ganglion; *ant. l.*, antennal or olfactory lobe; *ant. n.*, antennal nerve; *f. g.*, frontal ganglion of sympathetic nerve; *lbr. n.*, nerve to labrum; *x*, cross-nerve or commissure between the two hemispheres; *œ. c.*, œsophageal commissure to subœsophageal ganglion. 2. Side view of the brain and subœsophageal ganglion (lettering of brain as in Fig. 1); *s. g.*, stomatogastric or sympathetic nerve; *a. s. g.*, anterior, and *p. s. g.* posterior, sympathetic ganglia; *g.* 2, subœsophageal ganglion; *md.*, nerve to mandible; *mx.*, maxillary nerve; *ln.*, labial nerve; *n. l*, unknown nerve, perhaps salivary? 3. Interior view of the right half of the head, showing the brain in its natural position; *an.*, antenna; *cl.*, clypeus; *lbr.*, labrum; *m.*, mouth cavity; *md.*, mandible; *t.*, tongue; *œ.*, œsophagus; *c.*, crop; *en.*, right half of the endocranium or X-shaped bone, through the anterior angle of which the œsophagus passes, while the great mandibular muscles play in the lateral angles. The moon-shaped edge is that made by the knife passing through the center of the X. 4. View of brain from above (letters as before). 5. Subœsophageal ganglion from above: *t. c.*, commissure to the succeeding thoracic ganglion; other letters as before. Fig. 3 is enlarged eight times; all the rest twenty-five times.

Drawn from original dissections by the late Mr. Edward Burgess.—From Second Report U. S. Entomological Commission.

He finds in the *protocerebrum* of the insect (locust, etc.) all the constituent parts of the protocerebrum of crustacea. These are the layer of postretinal fibers, the ganglionic plate, the external chiasma, the external medullary mass, the protocerebral lobe, the ocellar nerves and lobes, the bridge of the cerebral lobes, and the middle (central) protocerebrum.

The *deutocerebrum* comprises the olfactory antennal lobes, and the dorsal lobe of the deutocerebrum. The deutocerebrum gives origin to four pairs of nerves, *i. e.*, (1) the antennary nerves; (2) the accessory antennal nerves; (3) the tegumental nerves; (4) the root of the stomatogastric ganglion.

The *tritocerebrum* is formed of a pair of lobes (tritocerebral lobes), which are united by a transverse commissure passing under the œsophagus. The lobes give origin to a nervous trunk, which is divided into two branches, *i. e.*, the labral nerves, and root of the frontal ganglion.

Dr. Saint Remy adopts Viallanes' classification, but he concludes that in Myriopoda the brain is divided into the "three ganglions which are perfectly comparable to the brain of the higher crustacea and of insects, though their structure is infinitely more simple." But in the brain of Arachnida he finds only the protocerebrum, and adds: "*Mais pour ce qui est de la seconde région du cerveau, ou ganglion rostro-mandibulaire, la détermination des homologies est plus délicate.*" The deutocerebrum of the insects, myriopods and crustaceans "*n'est pas représenté ici.*" He thinks that the rostro-mandibular ganglion of Arachnids is the homologue of the third region or tritocerebrum.

The shape and relations of the brain of insects is well shown by Fig. V.

Coming to Limulus we shall see that the brain does not include the rostro-mandibular ganglion found in spiders and scorpions, and that neither the tritocerebrum or the deutocerebrum is found, the brain representing the protocerebrum alone; or if the deutocerebrum is present it is not preœsophageal and is not yet fused with the archicerebrum.*

IV. Histology.

The histological elements of the brain of Limulus are closely similar to those of the Arachnidan brain, so ably described by Saint Remy. As in other Arthropods the histological constituents of the brain are the large ganglionic cells with abundant protoplasm, the punctuated or myeloid substance, the nervous fibers which form the origins or roots of the nerves, and the small ganglionic cells or nuclei.

These last-named cells unite to form certain bodies, the real nature and homology of which has made the study of this subject especially difficult. Indeed, the most striking feature of the brain of Limulus are what we called in our former memoir the convoluted, ruffle-like "nucleogenous bodies." They form cortical layers enveloping the cerebral and optic lobes, and where scattered inclose masses of fine fibrillar and myeloid or punctuated substance. These bodies appear at first sight to be composed of closely crowded nuclei, but when they are scattered they are seen to be small ganglionic cells. They appear to be the "ganglionic nuclei" (*gangliösen Kerne*) of Dietl† (p. 303, etc.) which he also refers to as "free protoplasmaless nuclei" (p. 496). See also Dietl's later paper (1878), where he thus defines these ganglion cells: "4. Kleine Zellen mit sehr schmalen Protoplasmasaum der trübe Nucleus enthält Nucleoli (Sinnesanschwellungen)," p. 14.

I also regard them as identical with the "*cellules chromatiques*" of Saint Remy. He describes them as "unipolar cells, so poor in protoplasm that their cellular outlines escape observation in sections," and adds: "Besides the extreme reduction of the protoplasmic body these elements present a remarkable peculiarity: the richness of their nucleus in chromatic substance capable of taking very distinctly the coloring matters, even after the prolonged action of osmic

* The terms protocerebrum, deutocerebrum, and tritocerebrum are rather cumbersome, and as they represent three distinct pre-œsophageal segments (arthromeres), it seems to us more convenient to call the protocerebrum the optic segment or division of the brain, because the principal lobes composing it are those sending nerves to the compound eyes and ocelli; so also the deutocerebrum might be denominated the antennal segment, and the tritocerebrum the labral segment. This nomenclature would well accord with the names mandibular, and first and second maxillary segments situated behind the mouth, the ganglia contained in them being called by the same names, mandibular, etc.

† Die Organization des Arthropodengehirns.

acid. Finally, what renders them specially interesting is that we only meet with them in the sensorial centers of the brain, where they form very dense masses. These elements are abundant in the Myriopods, where they are especially small and brightly colored; they likewise occur in the Arachnids and Onychophores. They are always in direct relation with the differentiations of the punctuated substance, and, in a general way, we have stated that they are far more numerous and present characters far more trenchant where the brain is higher in organization. Thus in the Myriopods they are especially abundant in the complicated brains of Julus and of Scutigera, and do not exist in the rudimentary brain of Geophilus. In the Arachnids we notice their presence in the highly developed optic lobes of Lycosids or of Phalangids, while they are replaced by small, less deeply stained nucleated cells and with visible protoplasm in the very simple lobe of Agalenids, or even by ordinary cells in the rudimentary lobe of the Pholcids." He calls these cells "*cellules chromatiques*," in reference to one of their salient characters, and we shall often use this term for those of Limulus, though rather preferring the name aprotoplasmic cells or small ganglion cells.

These small, aprotoplasmic, unipolar ganglion cells as contrasted with the large ganglion cells are represented in Pl. XII, fig. 6*a*, *smgc*, where their size as compared with the ordinary large ganglion cells is well brought out.

They are seen to be much smaller than the nuclei of the large ganglion cells, and their nuclei have usually two or three nucleoli, though the number may vary from 1 to 6. In the large ganglion cells the number of nucleoli varies from 1 to 4, there being usually two more distinct than the others.

In this ganglion, that of one of the median eyes, the fibrilla from each of the unipolar chromatic or aprotoplasmic ganglion cells is seen entering the tangled central white mass, and among the convoluted masses of fibrillæ are seen irregular masses of myeloid substance.

This myeloid or punctuated substance, common to the central white fibrillar substance of all Arthropod brain ganglia, and usually enveloped by the ganglion-cells, we have referred to as follows in our essay on the structure of the brain of the sessile-eyed crustacea:

The *punktsubstanz*, *marksubstanz* or myeloid substance, as we may designate it, differs in its topographical relations from that of the brain of Decapoda. This myeloid substance, which seems to be peculiar to the worms, mollusks, and especially the crustacea and insects, has been most thoroughly studied by Leydig. This is the central finely-granular part of the brain, in which granules have short irregular fibers passing through them. In his *Vom Bau des thierischen Körpers*, p. 89, Leydig thus refers to it:

"In the brain and ventral ganglia of the leech, of insects, and in the brain of the Gastropods (Schnecken) I observe that the stalks (stiele) of the ganglion-cells in nowise immediately arise as nerve-fibers, but are planted in a molecular mass or *punktsubstanz* situated in the center of the ganglion, and merged with this substance. It follows, from what I have seen, that there is no doubt *that the origin of the nerve-fibers first takes place from this central punktsubstanz*.

"This relation is the rule. But there also occur in the nerve-centers of the invertebrates single definitely situated ganglion cells, whose continuations become nerve-fibers without the intervention of a superadded punktsubstanz."

Leydig subsequently (p. 91) further describes this myeloid substance, stating that the granules composing it form a reticulated mass of fibrillæ, or, in other words, a tangled web of very fine fibers:

"We at present consider that by the passage of the continuation of the ganglion cells into the *punktsubstanz* this continuation becomes lost in the fine threads, and on the other side of the *punktsubstanz* the similar fibrillar substance forms the origin of the axis-cylinders arranged parallel to one another; so it is as good as certain *that the single axis-cylinder derives its fibrillar substance as a mixture from the most diverse ganglion-cells*."

The brain of Limulus is, as we have seen, composed of three pairs of ganglia, viz, the lateral optic lobes, the median optic lobes, and the cerebral lobes with their offshoots, the pair of mushroom bodies. We will begin our account of the topography of the brain with the first of these.

V. The Lateral-Eye Lobes or Ganglia.

(Pls. I, II, VI, VII, IX, XI.)

These are recognized without much difficulty, and are situated at the uppermost part of the brain, the convex contour of their anterior portion being visible from a surface view without a lens. The lobes are situated a little behind the middle of the brain, and are placed rather far apart, situated one on each side of the brain, there being a well-marked valley or depression between them. The brain seen from above is, then, slightly bilobed, but not so markedly so as in Arachnida. The two lateral-eye nerves arise from the lobes at a point considerably behind the

origin of the unpaired median-eye nerve, and nearly opposite the position of the median-eye lobe. The anterior division of the lobe* is rounded, somewhat pear-shaped, and more than twice as thick as the base of the nerves to which it gives rise (Pl. 1, Fig. 2). Each lobe is mostly made up of a tangled mass of nerve fibers proceeding from small ganglionic cells (chromatic cells) buried in the mass of the lobe (Pl. I, Figs. 1, 2, Pl. II, Figs. *7a*, *7b*; and young, VI. Fig. 1, Pl. VII. Fig. 2, which represents the entire lobe, and forming an irregular cylindrical sheet, or plate, passing through the lobe.† This layer is not, then, wholly a cortical one, but is in part internal, and may be called the chromatic-cellular layer of the lobe, and penetrates the lobes from beneath, being an offshoot from the mass of chromatic-cell layers impinging upon or partly enveloping the lower side of the lobes, as seen in Pl. VI, Fig. 1, *ch. c. layer*. In the young Limulus this layer is more external and cortical. These cells differ from the ordinary large ganglionic cells in having very little protoplasm enveloping the nucleus, the latter taking a deep stain, and thus being very distinct, while the nuclei take the carmine stain well. They might be called aprotoplasmic ganglion-cells. These cells appear to be identical with Saint Remy's chromatic cells. Many of these cells are scattered through the center of the lobe, especially in the lower portion. We shall refer to them as chromatic cells, or aprotoplasmic or small ganglion cells. We are not entirely satisfied with the term chromatic cells, as this does not describe their more fundamental nature or their small size. Similar chromatic cells are scattered throughout the inner aspect of the lobe, between the periphery and the chromatic-cell layer within.

These chromatic cells are plainly seen in the section represented by Pl. II, Figs. 7, *7a*, to be unipolar and to give off the fine fibers which form the tangled fibrillar mass constituting the greater part of the lobe. But besides these fibers throughout the tangled mass are to be seen irregular masses of the white myeloid or punctured substance (*punktsubstanz*) which appears to form a sort of network extending throughout the central part of the lobe. (See also Pls. XXI–XXIV, made from Dr. Gray's excellent photographs.)

As already stated, the space directly under the lateral-eye lobes is occupied with the ruffle-like masses of the mushroom bodies passing up from the middle on each side of the brain (Pl. I, Figs. 2, 5), and branches from the cortical mass of these ruffle-like plates or sheets envelope the lower and outer sides of the lateral optic lobes, until, as represented in Pl. I, Fig. 5, the lobes have disappeared and their place is taken by the chromatic cell layers. Layers of chromatic cells also appear in front between the lower faces of the lateral-eye lobes, as in Pl. VII, Fig. 2. The lower face of the lobes are thus seen to be partly enveloped by layers of chromatic cells.

The question now arises, have these layers of chromatic ganglion-cells forming in part the cortex of the lateral-eye lobes any homologues in the brain of Arachnida? Without having any sections of the brain of spiders with which to compare them, I am disposed to regard them as possibly identical with the *lame glomérulée* of the interior eye-lobe of Lycosa, etc., described by Saint Remy. (See his Pl. VII, Figs. 72–76, and Pl. VIII, Figs. 86–88, *l. gl.*) But until direct comparison be made between these structures in actual sections, it will be difficult to decide this point. Judging by Saint Remy's figures alone, they appear to be similar, but I have been unable to find the glomerules and nervous tubes described by him. At present the chromatic-cell layer of the lobes under consideration appear to me to be simpler in structure and less differentiated than in Arachnida. I have also been unable to detect any bodies homologous with the "medullary plates" of Saint Remy, and which form so characteristic a feature of the upper and lower optic lobes of the brain of Arachnids. In apparently lacking these highly specialized structures the brain of Limulus appears to be more primitive.

* This portion of the lobe is the *lame ganglionnaire* (*lg*) of Viallanes, who divides the optic ganglion into three masses, the most anterior being the "ganglionic plate or sheet, (*lame*). This sheet or mass is connected with the second mass (*me* of Viallanes' plate 10, Fig. 17)" by a bundle of chiasmic fibers or "external chiasma" (*chc*). The third mass (*mi*) is "united with the cerebral lobe (*lc*) by a short peduncle like the optic tract of Crustacea and Insects" (p. 415). These two posterior masses are represented in my Pl. II, Figs. 8, 9, and 10, *l. eye. b*[1] and *l. eye. b*[2]; Pl. VII, Fig. 2. I had regarded them as connected rather with the cerebral lobes than with the optic lobes, but now accept Viallanes view as to their true relationship.

† This layer is figured by Viallanes in his Pl. 10, Fig. 77, but not described. Pl. VII, Fig. 2*a. c. ch.* represents the "external chiasma" (*sic*) discovered and so named by Viallanes and fairly well seen in my sections.

VI. The Median-Eye Ganglia or Lobes.

(Pl. I, Figs. 5–7, 11, Figs. 8, 9, 10; Pl. III, Fig. 11, VII, Figs. 1, 2.)

After passing, in horizontal sections, down through the lateral-eye nerves and lobes the knife cuts through the origin of the median-eye nerves and the lobes or ganglia from which they originate.

These lobes are, in the adult brain, situated considerably below the plane of the lateral-eye lobes, and the origin of the bundle of nerve-fibers leading to the median-eye nerve is difficult to detect, owing to the fact that, so far as our sections show us, they are small, slender, quite irregular in shape, not being regularly pear-shaped or subspherical, and their fibers appear to be more or less continuous with the fibers of the cerebral lobes; in fact, they at first sight appear to be branches of the inner portion of the fibrous matter of the cerebral lobes. The two median-eye nerves being blended, within the brain as well as without, only dividing near the median eyes themselves, their cortical cells are also near together and not separated into distinct areas. I have had no sections either of the young or adult animal which have clearly shown the mode of origin of the fibers forming the origins or roots of the nerves, from any large ganglion-cells. The ganglia are more or less blended or coalesced with the cerebral ganglia, and I believe it will be difficult, if not impossible, to make them out unless we examine sections of the young after the first molt, or when about half an inch in length, exclusive of the caudal spine.*

I have been able to trace the origin of the median-eye nerve into the central part of the brain to the point *m. eye n.* in Pl. III, Fig. 11, and it appears probable that the large ganglion-cells which give origin to a part of the median-eye nerve are associated more or less intimately with those which supply the fibers, or a part of them, to the inner aspect of the cerebral lobes. We will, however, consider the large ganglion-cells, to be seen in the section represented at *m. eye gang.*, Pl. III, Fig. 11, as belonging to the median-eye lobe. This area of large ganglion-cells, with smaller ones interminglcd, is bilateral, the cells being arranged irregularly on each side of an irregular and very slightly marked median line which is clear of them.

We will now describe the sections passing through the blended median-eye nerves, and the double lobe from which the double nerve originates. In Pl. II, Fig. 8, the knife has passed through the middle of the median-eye nerve (*m. eye n.*). The nerve fibers from it pass in towards the middle of the brain and partially fuse with two masses (Pl. II, Fig. 9, *m. eye l.*) which appear as two horns or offshoots of the fibrous portion of the lateral-eye lobes. The triangular space between these two roots of the median-eye fibrillar masses is bounded posteriorly by the cerebral commissure (*c. com.*). The ganglion-cells scattered through this mass are arranged on each side of the obscurely-marked median line of the brain. As in this plane of the brain I can perceive no fibers from any of these ganglion-cells entering into the cerebral lobes, I take it that the cells in question send their fibers into the median-eye lobes and help build up the median-eye nerve. The fibers of the latter are also, with little doubt, reënforced with fibrillæ from the masses of chromatic or small ganglion-cells which envelop the nerve just before it passes out of the brain.

In Pl. III, Fig. 11, the cerebral commissure is complete, and what seems the right root of the median eye nerve is seen to penetrate farther into the center of the brain than in the two sections immediately above. In Pl. III, Fig. 12, the knife has passed just below the roots of the median eye nerve and the cylindrical plates or sheets of small ganglion or chromatic cells nearly meet under the nerve. This is also seen in Pl. III, Fig. 13, while in the section represented by Pl. III, Fig. 14, there are no traces of the median eye nerve, the ruffle-like cylinders of small ganglion cells being now crowded together under where the nerve passes out of the brain.

The relations of the median-eye lobes are well shown in the sections of a small Limulus, represented by Pl. VII, Figs. 1 and 2. In Fig. 1 is seen the horseshoe shaped bundle of fibers, inclosing the

* The limits of the fibrous portion of these lobes have been clearly distinguished by Viallanes (p. 416 and his Pl. II, Figs. 3 and 5, *goc.*, though in his model he does not represent the central mass of large and small ganglion cells. I now see that my Pl. VII, Figs. 1 and 2 represents the ganglia in question. It is the blending or fusion of the portions of these and the lateral-eye lobes adjacent to the cerebral lobes, which has rendered it so difficult for me to obtain a clear idea of their limits. In this respect the brain of Limulus differs remarkably from that of Crustacea or Insects, as well as Arachnida.

mass of large and small ganglion cells, with the roots of the fibers to which they give origin. The cellular mass belonging to each lobe is seen to be separated by a median space free from ganglion cells. (This large mass of cells, forming the bulk of each lobe, does not appear to be represented by Viallanes either in his figures of actual sections or of his wax model, and they form much larger and more bulky masses than he describes or figures.) In the section represented by Fig. 2, the roots of the median-eye nerves (*m. eye n. r.*) are seen on their outer aspect to be fused with the proximal end of the lateral-eye lobes.

Fig. 2*a* represents the bundle of twisted fibers forming the "external chiasma" of Viallanes; these fibers appear to end in irregular pear-shaped masses of punctured substance, and beyond them is the zone of internal chromatic cells (*ch. c. l.*). In Pl. VI, Fig. 1, at f' is seen on each side a fascia arising from the large ganglion cells in the lower part of the median-eye lobe, passing back into the cerebral lobes, and behind is a second fascia (f'').

VII. The Cerebral Ganglia or Lobes.

(Plates III, IV, V, 20, 21, VI, VII, VIII.)

The third and much the largest pair of lobes are the cerebral ganglia. They comprise the bulk of the brain when we take into account the masses of small ganglion cells constituting the "*corps pedonculé*" of Viallanes. The central fibrillar or white portion of these ganglia are very irregular in outline compared with the massive, more or less spherical cerebral lobes of the Arachnida; and the cortical masses of small ganglion cells which enclose and also ramify through the cerebral white mass are very different in disposition from the ganglionic cortex of the Arachnidan brain, and they are enormously developed in the brain of Limulus.

The white fibrillar portion of the cerebral lobes are arranged in two masses, one on each side of the median line of the brain. These lobes are very irregular in outline, slender, and apparently shrunken. They are narrow and thin, sending off irregular lateral lobules.* The cerebral lobes are connected posteriorly by a thick cerebral commissure (*c. com.*).

This commissure, as numerous sections show (Pls. II, Figs. 8, 9, 10; III, Figs. 11–13), consists of fibrillæ originating from the thin crescent-shaped central dense mass of small ganglion (chromatic) cells (*c. com. cortex*) near the posterior margin of the brain, and which overlies the median portion of the origin of the great commissures leading to the œsophageal ring.

The central or larger mass of the cerebral lobes does not pass much below the middle of the brain. It gives off the pairs of upper and lower tegumental nerves, and the posterior lobules, one on each side, serve as the origin of the great commissures connecting the brain with the œsophageal ring, which latter is originally formed by the coalescence of the neuromeres of the postoral cephalothoracic appendage-bearing segments.

In order to clearly bring out the relations of the cerebral lobes I will first describe the horizontal sections of the young Limulus when about 2 inches in length, exclusive of the caudal spine.

In a series of 43 sections the uppermost sections of the brain do not involve the fibrous matter of the cerebral lobes. The first fibrous portion encountered in cutting sections from above downwards are the two subparallel curved lateral-eye strands, Pl. VII, Fig. 1, *lat.-eye., n. r.*, which send fibers to the anterior horn or process of the median-eye lobes. Between these two strands is a thick, horseshoe shaped bundle of fibers, the incomplete circle opening anteriorly near the front of the brain, and inclosing two large groups of ganglion cells. These are the roots or origin of the median-eye nerves.

In the second section below the one just described (Pl. VII, Fig. 2) the knife passes through the lower part of the median-eye lobes and through the upper part of the cerebral lobes, but involving the larger central mass of the lobes. The œsophageal commissures are seen to be large and thick; the commissures are reinforced by the fibers sent off from the small group of large ganglion cells ($l\ g\ c'''$) (those on the other side, not seen in this section). There is also a group of large ganglion cells ($l\ g\ c'$) on each side of the base of the brain.

In or near the central part of the cerebral lobes, Pl. VI, Fig. 1, in the fourth and fifth sections below the one just described, the mode of composition of the fibrous portion of the lobes is seen.

*These lateral lobules are the second and third masses of the lateral-eye lobes, according to Viallanes.

From the numerous large ganglion cells on each side of the median line of the brain, between the roots of the median-eye nerves, is sent off an anterior bundle of fibers (*f'*) which passes in and across the fibrous portion of the cerebral lobes, the fibers of each bundle meeting in the middle, so as to inclose an incomplete circle; a second set of fibers (*f''*) behind the first is to be seen behind; and this is succeeded by the transverse fibers which originate from the base of the œsophageal commissures, these fibers in part originating from the basal masses of large ganglion cells (*l g c*).

On the side of the main fibrous masses, scattered throughout the cortical plates of small ganglion cells, are seen, as at *m. b.*, the sections of irregular lateral branches of the mushroom bodies which pass upwards from the ventral portion of the brain. In this section are also well shown the relations of the ganglia of the first pair of appendages with the fibers from the œsophageal commissures traversing the mass of large ganglion cells, the latter sending backwards their fibers, but most of them sending fibers to form the nerves to the first pair of appendages (*1st app. n.*).

In the second cut below the section just described the knife passes through the lower border of the cerebral lobes, where the fibers are thrown together in tangled masses, arising from the groups of large ganglion cells on each side.

In the next cut the fibrous portion of the cerebral lobes is formed of two halves, which are bulbous at their base, and in front give rise to the lower tegumental nerves (Pl. VIII, Fig. 1, *l t n.*).

Just below this the knife passes through the scattered bundles of fibers or branches of the mushroom body passing up from the under side of the brain (Pl. VIII, Fig. 2).

The brain here largely consists of plates of small-ganglion or mushroom-body cells, with portions of the fibrous bundles on each side of the median line, which seem to give rise to the median tegumental or frontal nerve, *m. n.*, and larger fragments on the outer sides. Near the posterior end of the brain are two masses of large ganglion cells. Just below the section just described the knife passes through the plane below which no nerves are sent off, and below which there are no large ganglion cells. This plane is situated between the second and lower third of the brain, and below it the mass of the brain is made up of plates or sheets of small ganglion cells inclosing white or fibrous masses, which pass up and, uniting, aid in forming the white or fibrous lobes and lobules of the cerebral ganglia (Pl. VIII, Fig. 4). (These plates are the lobes of the mushroom bodies.)

Thus the fibrous portion of the cerebral ganglia are composed of fibers from the comparatively few large ganglion cells and the vastly more numerous and more minute fibers emitted from the small ganglion or chromatic cells forming portions of the mushroom bodies; whether the fibers from the large cells pass backwards continuously from the cerebral lobes through the ganglia composing the œsophageal ring, and unite with certain fibers from the said ring to form the abdominal cords, or not, is a question yet to be solved.

Some peculiarities are to be seen in the sections of the brain of the fully grown specimens (10 inches long, exclusive of the caudal spine) which are not to be observed, so far as our experience goes, in the smaller ones. These we will proceed to indicate.

Pl. II, Fig. 8, represents a section passing through the median eye nerve and its lobes (*m. eye n.* and *m. eye-lobe*) and the upper part of the cerebral lobes. The knife has passed through the ends of the cerebral commissure (*c. com.*), unsheathed, especially posteriorly, by the small ganglion cells; on each side of the central mass of large and small ganglion cells is the irregular branched mass of white fibrous substance, which is small in proportion to the enormously developed masses of small ganglion cells of the mushroom bodies, with their inclosed masses of fibrous and myeloid substance on each side. In two sections farther down, Pl. II, Fig. 9, the cerebral commissure is seen on the left side to be continuous with the white fibrous matter of the left cerebral lobe, and on the right side are seen a few large ganglion cells. In the next section below, the halves of the cerebral commissures are seen to touch each other (Fig. 10); while in two sections still lower down (Pl. III, Fig. 11), the commissure is complete, with its posterior cortical sheath of chromatic cells. The white, fibrous posterior region of the cerebral lobes is now larger, and the two lobes, united behind by the commissure, are anteriorly fused with the lobes of the lateral eyes (Figs. 11, 12).

Still lower down (Pl. III, Fig. 12) this section cutting through the upper tegumental nerves (*u. teg. n.*) the œsophageal commissure on the right side of the brain is involved. The white por-

tion of the cerebral lobes is now smaller. One of the sheets of small ganglion cells is seen on the left side to throw off a sinuous bundle of fibers to aid in forming the œsophageal commissure of the left side (*fasc.*); and a little within is seen on the same side a group of large central ganglion cells.

In the section represented by Pl. III, Fig. 13, the central masses of large ganglion cells, directly under the median-eye lobes are seen to send their fibers outward from the median line of the brain, and on the left side the sheets of small ganglion cells (*sm. g. c.*) are distinctly seen sending delicate fibers into the commissure. In a few sections lower down (Pl. IV, Fig. 16) the anterior region of the white or fibrous portion of the lateral-eye lobes has diminished, while the section passes through near the middle of the œsophageal commissures, this section also passing through the middle of the entire brain, just at the lower edge of the pair of fronto-inferior tegumental nerves (the nerves to the sensorial pit, of Viallanes). At *gc.* is seen a group of large ganglion cells, sending a bundle of fibers to aid in making up the œsophageal commissures.

Fig. 17 (compare the transverse sections, Pl. XIII, Figs. 10, 11) represents a section through the two groups of central and the lateral groups of cerebral ganglion cells; of the latter Fig. 18 is an enlarged view. On the right side is seen a portion of the stalk of the mushroom-body (*st. m. b.*). In a few sections lower down the large ganglion cells are seen to be unipolar and to send their fibers into the œsophageal commissures, and the small ganglion or chromatic cells are also seen sending their fibers into the commissure. Fig. 19 is an enlarged portion a few sections lower down, showing the bundle of fibers arising from the group of lateral cerebral ganglion cells.

Figs. 20 and 21 represent sections passing through the lower part of the cerebral lobes, where the central group of large ganglion cells is larger; at *l. gc.* is an unusually large ganglion cell with a very thick fiber passing from it into the commissure.

In a few sections below (Figs. 21, 22, 23) the large ganglion cells disappear, and also the commissures, the lower third of the brain passing below the level of the œsophageal commissures, and the mass being filled with the sheets of chromatic ganglion cells. (See Pl. XXXI).

The longitudinal (sagittal) sections of the brain (Pl. IX, X, Figs. 1–13, and Pl. XXXVI).—An examination of the figures on Pls. IX and X will show how large a proportion of the brain is occupied by the cortical masses of chromatic cells, which, in addition to their forming the sides of the brain, occupy the lower half of the central portion. In Pl. XX, Fig. 1, the cut through one side of the brain passes through the outside of the base of the lateral-eye nerves, and also shaves the nerve of the median eyes, but no large ganglion cells are involved, or the central fibrous substance of the cerebral lobes. In succeeding sections nearer the median line of the brain, as those represented by Pl. IX, Figs. 2, 4,* and especially 3, the relations of the lateral-eye lobes to the cerebral lobes are brought out, the two lobes being separated by a thick screen of chromatin-cell plates or sheets, with their inclosed masses of fibrillar and myeloid substance belonging to the mushroom bodies.

The relations of the cortical masses of large ganglion cells of the median-eye and cerebral lobes are to be seen in Pl. X, Fig. 11, the median-eye lobes being situated above and a little in front of the cerebral large ganglion cells. In Pl. VIII, Figs. 5, 6, 7, three longitudinal sections of the brain of the younger Limulus, which is larger and thinner than in very large specimens, are represented, one (Fig. 5) showing the lateral-eye lobe and nerve, this section passing through the œsophageal ring, while the other (Fig. 6) illustrates a section passing through the median-eye lobe and nerve, and also the cerebral lobe. This section may be compared with that represented by Pl. X, Fig. 11, of the large Limulus.

The transverse sections of the brain (Pls. XI–XVI and XXXII).—In the large adult Limulus the transverse sections show well the great amount of space taken up by the (more or less) cylindrical sheets of chromatic cells of the mushroom-bodies. In the anterior sections, involving the origin of the lateral-eye nerves, the sections represented by Pl. XI, Figs. 1, 2, 3, and 5, pass exclusively through the sheets of chromatic cells, which are thus seen to form not only the lower portion but also the anterior region of the brain. At Fig. 3 the lateral-eye lobe on the right side is involved.

In the sections behind these toward the middle of the brain the anterior region of the cerebral lobes is cut through, and the portions of the white or fibrous matter intersected are seen to be confined, as in Figs. 4 and 5, to the upper third of the brain.

* The figure (4) referring to this figure has been inadvertently omitted by the lithographer.

As the knife passes through the posterior region of the lateral-eye lobes it also cuts through the upper and anterior region of the median-eye lobes (Figs. 4 and 5).

In the next section figured, Fig. 6, the knife passed behind the lateral-eye lobes, involving the median-eye lobes, and also the anterior region of the cerebral lobes which send lobules into the lower part of the brain. The section, like all the others, being a little oblique, show the white fibrous matter on the right side penetrating to the bottom of the brain. Fig. 6*a* is an enlarged view of the central portion of the left median eye lobe, showing the large ganglion cells, which are seen to vary much in size; and the small ganglionic or chromatic cells forming the semicircular sheet or plate, and inclosing the fibrous matter as well as the myeloid or punctured substance. The inner layers of aprotoplasmic or chromatic cells (small ganglion cells) are here seen to send their fibrillæ in toward the center of the mass inclosed by the cells.

These small ganglion cells contain usually more than one nucleolus—usually two or three—and I have counted in them from 1 to 6 nucleoli. The number of nucleoli in the large ganglion cells varies from 1 to 4, but there are usually two. These cells are seen to be unipolar and to send their nerve fibers directly across toward the group of cells in the opposite lobe, though no distinct commissure is thus formed.

In a few sections farther back the ganglion cells, both large and small, are arranged as in Pl. XI, Fig. 7, and Pl. XII, Fig. 8 shows their arrangement and relations to the central and lateral large ganglion cells in a section made still farther back, near the middle of the brain.

In the section represented by Pl. XII, Fig. 9, which passes through near the middle of the brain, the two masses of large ganglion cells of the median-eye lobes have coalesced, while the cerebral ganglia are now larger, and the central and cortical groups of large ganglion cells are larger than in Fig. 8. In the third section succeeding large ganglion cells appear on the left side. In Pl. XIII, Fig. 10, the cortical groups of large ganglion cells disappear, and those of the central groups become more numerous. This section involves the origin of the œsophageal ring, and now the posterior end of the brain becomes flatter, wider, and not so deep. Pl. XIII, Fig. 12, represents the posterior portion of the cerebral lobe, with the thick cerebral commissures. In the second section still farther back the ganglion of the first pair of appendages, Pl. XIII, Fig. 13, is interscected, and in Pl. XIV, Fig. 17, the knife passes through the œsophageal ring just behind the ganglia of the first pair of appendages.

In the transverse sections of the brain of a small Limulus, about 2 inches long exclusive of the caudal spine, the details brought out, in addition to those already pointed out, are the very distinct basal portions of the white fibrous portion of the cerebral lobes. These are seen in Pl. XIV, Fig. 18, to send an irregular branch on each side of the median line of the brain (*m*) up to the top of the brain, each branch sending three irregular lobes out to the side of the brain, besides a number of smaller ones which are seen to be cut across, and enveloped by the thick sheets or cylinders of small ganglionic or chromatic cells. (These branches of the cerebral lobes are what Viallanes regards as the stalk of the mushroom or pedunculated bodies). In Fig. 18 the median fissure or space (*m*) between the sausage-like groups of chromatic cells is seen more distinctly than in the fully grown individuals. In this section also the central groups of large ganglion cells (*clgc*) are seen above the cerebral commissure (*c. com*), and are also arranged one group on each side of the median line of the brain.

Pl. XV, Fig. 20, represents a section through the hindermost portion of the brain, the section also passing through the ganglia of the first pair of appendages. It will also be seen here, as in Pl. VI, that the pair of ganglia of the first pair of appendages are quite distinct from the brain, the nerves to these appendages (*1st app. n.*) arising from the mass of large ganglion cells forming a part of the œsophageal ring.

VIII. Results compared with those of other observers.

As may be seen from the preceding descriptions and by reference to the plates, the results of our examination of the brain of the adult Limulus, made with every possible care and pains, and based on many hundred sections, cut not only in a horizontal, but also longitudinal and transverse direction, are the following: The brain of this merostome is composed of but three pairs of lobes,

i. e., two pairs of eye-lobes or ganglia, viz.—first, those which send nerves to the lateral eyes; second, those which innervate the median eyes; and, third, the cerebral ganglia, which, with the mushroom bodies, form the chief portion of the brain. We have seen that the ganglia of the first pair of appendages are separate from the prestomial or prœsophageal brain mass. Hence we throwout these ganglia in our consideration of the constituents of the brain proper.

Prof. Patton, though he has not published any observations on the structure of the brain of the adult Limulus, in his article on the "Origin of Vertebrates from Arachnids" briefly describes (pp. 336-346) the development of the "cephalic lobes" and of the eyes of the embryo of Limulus. Patton does not give details of the structure of the brain of the embryo, only stating such facts as have a bearing on his remarkable theoretical conclusions,* reserving a full description for a future paper. On pages 338 and 339, however, he gives "diagrams" and a "semidiagrammatic" view of the brain of the embryo Limulus and refers to two pairs of median eyes, with their neuromeres, and on page 343 gives a figure of the "fore and mid brain of young larva of Limulus (just hatched) seen from neural surface," in which four prœsophageal neuromeres with their nerves are represented. Deferring to a few pages further on in this essay, the consideration of the number of brain neuromeres in the embryo and larva of Limulus, we will simply remark that we have, after repeated examinations, been unable to find more than a single pair of median eyes† in the embryo or larval Limulus, nor have we been able to detect more than three pairs of neuromeres in front of those innervating the first pair of appendages, these three pairs of neuromeres finally constituting the brain.

Our studies as regards the median-eye lobes entirely confirm those published by Kishinyoue, in his excellent work on the development of the Japanese *Limulus longispina*. He remarks:

About two weeks before the hatching of the embryo the brain proper becomes divided into two transverse portions by a constriction (Fig. 69). Thus the brain of *Limulus* may be divided into four parts—the ganglion of the median eyes, the ganglion of the lateral eyes, and the anterior and posterior portions of the brain proper.

These last two portions form apparently the cerebral lobes and mushroom bodies. Mr. Kishinyoue has also written me, since his paper was published, that he had only observed a single pair of median eyes.

The only other author besides myself who has studied the brain of the adult Limulus is M. Viallanes. An abstract of his paper read before the French Academy, December 1, 1890, appeared in the Journal of the Royal Microscopical Society, for February, 1891.

The author considers that the brain in *Limulus polyphemus* (this being the species investigated by him) "gives origin to the ocellar nerve," to the nerve of the compound eye, to the chelicéral nerve, to the stomatogastric nerve." We copy his description of the brain:

Structure du cerveau.—Le cerveau se compose de deux paires de centres ganglionnaires. La première est essentiellement constituée comme le *protocérébron* des autres arthropodes et doit être désignée sous ce nom. Quant à la seconde, quelques doutes pouvant encore subsister sur ses homologies, je la désignerai provisoirement sous le nom de *cerveau postérieur*.

Protocérébron.—Il se compose d'une paire de nodules fibreux ou lobes protocérébraux relativement petite, réunis sur la ligne médiane par une commissure *préœsophagienne*. Les lobes protocérébraux sont partiellement revêtus d'une écorce de grandes cellules unipolaires; et chacun d'eux donne naissance eau nerf‡ de l'ocelle correspondant.

Quant au nerf de l'œil composé, il s'unit au lobe protocérébral correspondant, non pas directement, mais par l'intermédiaire d'une formation comparable dans ses traits essentiels au lobe optique des insectes et des crustacés, car on y reconnaît les homologues de la lame ganglionnaire, du chiasma externe, des masses médullaires externe et interne; mais chez le Limule ce lobe optique est très petit relativement et enfoui au sein de la masse du cerveau, au lieu d'être écarté de celui-ci et en contact immédiat avec l'œil composé. Chez le Limule, le nerf optique est donc constitué par des fibres postrétiniennes étirées à l'extrême.

A chacun des lobes protocérébraux est annexé un organe qui, en raison de ses rapports anatomiques et de sa structure histologique, doit être assimilé au *corps pédonculé* des insectes.

* With Patton's attempt to derive the vertebrates from forms comparatively high, so specialized and modified as the scorpions and spiders, to say nothing of Limulus, we have little sympathy, regarding them not only as unsound, but as tending to lead to inaccurate observations. On general grounds the attempt to derive the vertebrates from any but the most primitive and generalized vermian forms would seem to be hazardous, the Arthropoda being a specialized and completed branch of the animal series.

† Patton considers that a diverticulum of the median eyebulb "represents, in all probability, a pair of eyes belonging to the first brain segment," and in the next paragraph refers to "the three fused ocelli of Limulus" (p. 344).

As we have already stated M. Viallanes' classification of the regions of the Crustacean and insect brain into three regions, viz, proto, deuto, and tritocerebrum, does not apply to that of Limulus. In my preliminary paper I pointed out that no deutocerebrum or tritocerebrum is represented in the brain of Limulus, and it is to be observed that Viallanes regards the brain as composed of two pairs of ganglia, the first being the protocerebrum, while as to the second he is doubtful, and provisionally calls it the "cerveau postérieur." Viallanes "protocerebrum" is what we regard as the brain proper, and consists originally of three pairs of neuromeres, becoming respectively the ocellar or median-eye ganglia, the lateral-eye ganglia, and the cerebral ganglia.

What Viallanes regards as the posterior brain, and as to the homologies of which he expresses himself as in doubt, we regard as a part of the œsophageal ring, and as postcerebral. This posterior brain gives rise to the cheliceral nerves. The "Commissure transverse pre-œsophagienne" I have detected since Viallanes has called attention to it.

Throwing out then, Viallanes *cerveau postérieur*,* as not forming a part of the genuine brain of Limulus, we will return to the brain proper, or prestomial mass, viz, the protocerebrum of Viallanes.

IX.—THE HOMOLOGIES OF THE SO-CALLED "NUCLEOGENOUS" OR "PEDUNCULATED BODIES."

M. Viallanes describes at some length the structure of the series of plates which we originally† called collectively the "nucleogenous bodies," and the nature and homologies of which seemed to us problematical. He remarks: "To each of the protocerebral lobes is annexed an organ which, by reason of its anatomical relations and its histological structure, should be assimilated to the pedunculated body of insects. The pedunculated body of Limulus has an arborescent form. The lower extremity of its stalk penetrates into the corresponding protocerebral lobe, its upper extremity is divided dichotomously into a great number of branches. These last, which end in truncated extremities, are entirely covered by a thick cortex of small cells very deficient in protoplasm, very deeply colored by stains, emitting very fine fibrillæ, in a word rigorously similar to the elements which form the cellular vestiture of the pedunculated body of insects."

The pedunculated body attains in the Limulus an extraordinary development greater than any other Arthropod known, because it by itself alone forms certainly at least $\frac{1}{10}$ of the total mass of the brain. This fact is all the more remarkable since up to the present time and not without important reason it has been agreed to consider the development of the pedunculated body as correlated to that of the mental faculties (pp. 2–3).

For years the true relations of these masses or plates which I have called the "nucleogenous bodies" have been a great puzzle to me; they are so numerous and form so large a proportion of the brain; but after an examination of the figures in Viallanes final work I am led to accept his interpetation of these bodies, which he appears to regard as "annexed" to the cerebral lobes. A re-examination of my sections and of my figures, which, however, do not show so clearly as his Pl. x, Fig. 18, the entire stalk of the body, or its intimate connection at its base with the cerebral lobes, leads me to adopt Viallanes view. At the same time there is a remarkable difference observable between these mushroom or pedunculated bodies and those of insects and spiders, a difference to which Viallanes does not refer. This stalk, however, is in part seen in the sections represented by my Pl. xiv, Fig. 18, *st. m. b.*, where the stalk is seen to arise from the bulbous or lateral portion of the cerebral lobes (*b. c. l.*), and to send off an ascending branch, and lateral branches. In Pl. xxxiv, the artotype from a microphotograph of the same section faintly represents the cerebral lobes, and the stalk of the mushroom body arising from the lateral or bulbous portion.

We will first (1) consider their resemblance to the mushroom or pedunculated bodies of insects; (2) their resemblance to or lack of resemblance or homology with the stratified body of the Arachnid brain; (3) their absence, *i. e.*, the unbranched and simple condition of the paired cerebral lobes or ganglia in the freshly hatched Limulus larva.

The mushroom bodies of Dujardin; the two mushroom bodies, with their stems, of Newton, or the pedunculated bodies of Viallanes, and which I have, after Dujardin, called collectively the

* In his last paper Viallanes regards this as the deutocerebrum.

† Farther studies on the brain of *Limulus polyphemus*. Zool. Anzeiger, 20 April, 1891. That the cheliceral nerves are correctly named is doubtful. The so-called chelicera or first pair of appendages of Limulus may be found to correspond to the antennæ or first pair of appendages of the spider discovered by Jarowosky.

mushroom bodies, form a characteristic portion of the brain of adult insects. They have not yet been found to be present in the Synaptera, but occur in the larvæ, at least of those of most metamorphic insects (Lepidoptera and Hymenoptera), though not yet found in the larvæ of Diptera.

FIG. VI.—Section through the brain of *Caloptenus bivittatus* in the third larval stage, showing the two hemispheres or sides of the brain and the ocelli and ocellar nerves, which are seen to arise from the top of the hemispheres directly over the calices; o. *cal.*, outer calyx of left mushroom body. The lighter portions represent the granulo-fibrous central part of the brain, and the dark the cortical ganglionic cells.

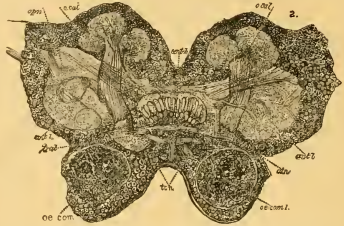

FIG. VII.—Section through the brain of adult *Caloptenus spretus*, passing through the mushroom bodies; o. *cal.*, outer calyx; *centr. b.*, central body; *ant. l.*, antennæ lobe; *op. n.*, optic nerve; œ, *com. l.*, cerebral lobe.

I have found these bodies in the nymphs of the locust (*Caloptenus spretus*), but not in the embryo just before hatching. They occur in the third larval or nymph stage of this insect, and in my essay I stated: "It is evident that by the end of the first larval stage the brain attains the development seen in the third larval state of the two-banded species" (*C. bivittatus*).

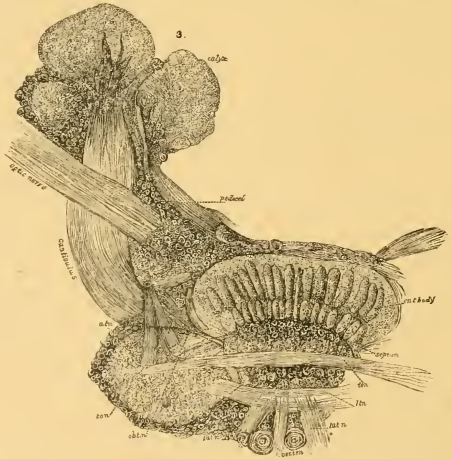

FIG. VIII.—Enlarged view of the trabecula and its nerves, of the mushroom body, its calices and double stalk (*cauliculus and pedicel*), and the origin of the optic nerve.

The result of my studies on the brain of the embryo locust was that from the "embryonic cerebral lobes are eventually developed the central body and the two mushroom bodies" (p. 237). Fig VI, copied from my essay (Pl. XII, Fig. 1), shows the early condition of the mushroom bodies

and their undoubted origin from the cerebral ganglia. Hence these bodies appear to be differentiations of the cerebral ganglia or lobes, having no connection either with the optic or with the antennal lobes. These bodies have, as stated in my essay, attracted a good deal of attention from writers on the brains of insects.

Dujardin, in 1850, first drew attention to them. His memoir we have not at hand to refer to, but as stated by Newton—*

"Dujardin pointed out that in some insects there were to be seen upon the upper part of the brain certain convoluted portions which he compared to the convolutions of the mammalian brain, and, inasmuch as they seemed to be more developed in those insects which are remarkable for their intelligence, such as ants, bees, wasps, etc., he

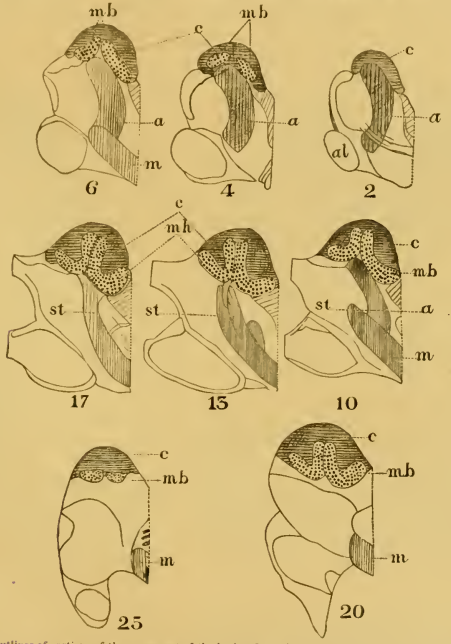

FIG. IX.—Diagrammatic outlines of sections of the upper part of the brain of a cockroach. Only one side of the brain is here represented. The numbers indicate the position in the series of 34 sections into which this brain was cut. *Mb*, mushroom bodies with their cellular covering; *c*, and their stems (*al*); *a* anterior nervous mass; *m*, median nervous mass.—After Newton.

seemed to think the intelligence of insects stood in direct relationship to the development of these bodies. The form of these structures is described by the same author as being, when fully developed, as in the bee, like a pair of disks upon each side, each disk being folded together and bent downward before and behind, its border being thickened and the inner portion radiated. By very careful dissection he found these bodies to be connected on each side with a short pedicle, which bifurcates below to end in two tubercles. One of these tubercles is directed toward the middle line, and approaches but does not touch the corresponding process of the opposite side. The second tubercle is directed forward, and is in close relation to the front wall of the head, being only covered by the

* On the Brain of the Cockroach. By E. T. Newton. Quart. Journ. Microscopical Science, July, 1879, II, pp. 341, 342.

pia mater [neurilemma]. These convoluted bodies and the stalks upon which they are mounted are compared by Dujardin to certain kinds of mushrooms, and this idea has been retained by more recent writers on the subject."

The form of the mushroom body is much more complicated in the bee or ant than in insects of other orders. In the cockroach and in other Orthoptera, notably the locust, the four divisions of the calices are united into two, while the structure of the calyx in the cockroach is quite different from that of the locust. Mr. Newton, in his description, notwithstanding Dujardin's statement, appears to practically limit the term "mushroom body" to the cap or calyx on the end of the stalk. In the following description we apply the term "mushroom body" to the entire structure, including the base or trabecula, the double stalk, and the cap or calyx. (Pp. 231, 232.)

It may be seen by reference to my figures and those copied from Newton (Fig. IX) and from Viallanes (Figs. X, XI), that the mushroom bodies, though arising from about the middle and lower third of the brain, are mainly contained in the upper region of the brain, this being the position

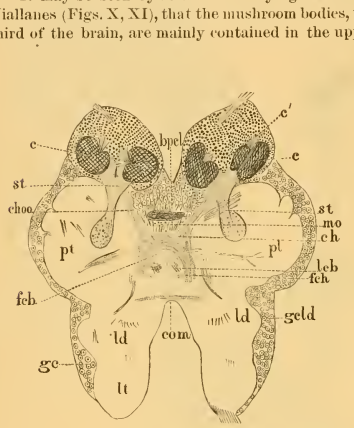

FIG. X.—Transverse section through the brain of the locust (Œdipoda and Caloptenus): *c'*, lower part of *c*, calyx, of mushroom body; *st*, stalk of the same; *b*, *pcl*, bridge of the protocerebral lobes; *mo*, nerve of median ocellus; *ch*, transverse fascia of the optico-olfactory chiasma; *feb*, fibrous region of the central body; *teb*, tubercle of the central body; *fch*, descending fascia of the optico-olfactory chiasma; *choo*, superior fascia of the optico-olfactory chiasma; *pt*, *pl*, protocerebral lobes; *ld*, dorsal lobe of the deuto-cerebrum; *lt*, trito-cerebral lobe; *geld*, *gc*, ganglion cells.—After Viallanes.

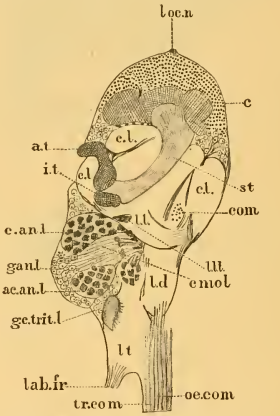

FIG. XI.—Sagittal section through the brain of the locust: *l. oc. n*, lateral ocellus nerve; *at*, anterior tubercle of the pedunculated body; *il*, internal tubercle of the pedunculated body; *cl*, cerebral lobes; *ll*, lateral lobe of the middle protocerebron; *com*, commissural cord; *c. an. l.*, cortical layer of the olfactory lobe; *cmol*, central mass of the olfactory lobe; *ac. an. l*, fibers uniting the median lobe of the protocerebron with dorsal lobes of the deutocerebron; *gc.*, *trit*, *l*, ganglionated cortex of the trito-cerebral lobe; *g an. l*, cortex of antennal (olfactory) lobe; *lab. fr*, labro-frontal nerve; *oe. com*, œsophageal commissure; *tr. com*, transverse commissure of œsophageal ring; other letters as in Fig. X.—After Viallanes.

of the caps of the mushroom, or calyces, these in part, as in the figures of Viallanes, forming two lobe-like protuberances (*c*, *c'*), the base of the stalk scarcely reaching the middle of the brain; in fact, being confined to the upper third of the brain. But in Limulus the masses of aprotoplasmic cells, with the fibrillæ arising from them, constitute nearly the lower half of the entire brain, besides forming a thick cortical envelope on the sides and in front and behind, and constituting, as M. Viallanes himself declares, $\frac{9}{100}$ of the whole brain*. I was led, therefore, to think that these structures were not the homologues of the mushroom bodies of insects, but rather the cortical portion of the cerebral ganglia, with its lobules, besides forming a part of the cortex of the optic lobes; all the fibrous or fibrillar portion of the brain being in part derived from what we have variously called the chromatic or aprotoplasmic, or small ganglion cells, and in part from what we call the

* This is somewhat of an exaggeration, and $\frac{80}{100}$ would seem to be nearer the correct proportion.

large ganglion, viz, the normal ganglion cells, in which the nucleus is surrounded by an abundant protoplasm.

It should also be observed that the mushroom bodies are best developed in adult insects, and especially in those of a high degree of intelligence. Now Limulus is low in the plane of intelligence. It burrows in the mud and in a haphazard way devours whatever worms and other soft-bodied animals it can obtain with its spiny-based legs.

On the other hand we were, before reading Viallane's final memoir, inclined to homologize the "nucleogenus bodies" of Limulus in part with the cortical masses of chromatic cells figured by Saint Remy (Figs. XII and XIII *l. ol.*) which envelop the optic lobes of spiders and the cerebral lobes of the scorpion (Fig. XIV *a. gang. m.*).

Whether a pedunculated body is present in the brain of myriopods appears from the careful researches of Saint Remy to be a matter of doubt. He does not seem to have detected any organs like them in the genera he investigated except in Julus, where he observed some vestiges which he compares to the pedunculated bodies of insects. In Scutigera (Cermatia) he discovered what he doubtfully homologizes with the pedunculated bodies of insects, remarking as follows:

The homologies of the complicated apparatus that we have just described are difficult—we may even say impossible—to establish with certainty. The general aspect and the disposition of the principal parts leads one at first to think that this ensemble represents the pedunculated body so constant in insects and the vestiges of which we have found in Julus. But when we examine the thing more closely and push the comparison more thoroughly we immediately perceive that the resemblance is absolutely superficial and that we can not find points of precise resemblance between the portions of our apparatus and those of the pedunculated body of insects. We are here even less well informed than in Julus because there are wanting the relations with the optic lobe (commissures of Bellonci) which have served as in this case to affirm the existence of a rudimentary pedunculated body represented by a calyx.

From the lack of facts of this kind it must be acknowledged that we have to content ourselves with hypotheses, though quite plausible ones. Without seeking to compare these organs in their details, we shall regard them as very probably homologues. What are, indeed, the constituent parts of the pedunculated body of insects? An accumulation of chromatic cells in relation with a system of medullary stalks which are planted in the protocerebron, and end abruptly in the midst (*an sein*) of the punctuated substance. We shall find the same structure and the same arrangements in the pedunculated organs of Scutigera. The peduncles end near the median line, as does the beam (trabecula), and the internal tubercle ends near the neurilemma, as the anterior horn in these last. The thin ganglionic masses seem to play, opposite these parts, the same role as the calices opposite (*vis-à-vis*) the horn and the beam (*poutre*) (pp. 74, 75).

In Peripatus also Saint Remy describes and figures a system of plates and a medullary mass perhaps comparable to the pedunculated organ of Scutigera, as he states on p. 242:

Ce système des lames et de la masse médullaire peut être comparé à l'organe pédonculé de la Scutigère. Ici comme chez la Scutigère, nous avons un organe médullaire qui recueille, d'une part, les prolongements de petites cellules chromatiques pauvres en protoplasma, et est en relation, d'outre part, avec des pièces qui s'enfoncent dans la substance ponctuée et se terminent franchement sans contracter de rapports à l'extremité avec d'autres régions. Mais, outre ce rapprochment fondé exclusivement sur des caracteres generaux, il est possible d'en faire un autre avec le corps pédonculé des insectes, basé sur les mêmes caracteres et appuyé de plus sur un fait anatomique interressant, l'existence de relations entre ces organs et le lobe olfactif, ainsi que la région qui donne naissance au pédicule optique, disposition commune à l'organe que nous venons d'etudier chez le Péripate et au corps pédonculé des insectes.

Under the circumstances, then, we were at first unable to agree with M. Viallanes that what he regards as pedunculated bodies are really such, nor did they appear to be the homologues of the problematical organs in the brain of Onychophora (Peripatus), or of Myriopoda. Further and very extended examination of the brain of young Limuli after their first molt, and when they are less than an inch long, exclusive of the caudal spine, are urgently needed to finally settle this and other difficult points in the homologies of the brain of Limulus.

X. COMPARISON OF THE BRAIN OF LIMULUS WITH THAT OF ARACHNIDA.

Thanks to the able and very detailed account and beautiful figures of Dr. Saint Remy, we now have a means or standard of comparison in studying the brain of Limulus which has not hitherto been afforded us, and which have greatly aided us in coming to a better appreciation of the nature of the brain of Limulus. There seems little doubt but that the brain in question is in its general features much like that of Arachnida. This is largely owing to the similarity in the

shape and position of the optic ganglia or lobes, and the similar relations in the mode of origin of the optic nerves; both the Arachnida and Merostomata having median and lateral eyes with a, in general, similar position in respect to the exterior of the head. Besides this, neither class possesses optic ganglia closely resembling those of insects and Decapod crustacea.

And yet there is a noteworthy difference between the brain of Limulus and of Arachnida. In the latter the cerebral ganglia are large and well developed, forming, we should roughly estimate, two thirds to three-fourths of the brain. The central medullary or white fibrous portion is largely developed, forming the bulk of the cerebral ganglia, and is more or less spherical in shape, while the cortical layers or masses of large ganglion cells are large and thick, the cells themselves being abundant, whereas in Limulus they are scanty, forming isolated small groups. Reference to the accompanying figures, copied from Saint Remy's work, will show the structure of the Arachnid brain together with the resemblance to and the difference from that of Limulus.

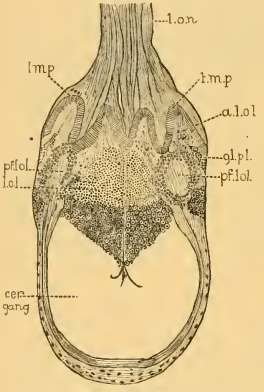

FIG. XII.—Brain of *Lycosa narbonensis* Walck., horizontal section passing through the middle of the middle segment of the optic lobes and through the lower medullary plate, and through the middle part of the lower medullary mass. *l. o. n.*, lower optic nerve; *l. m. p.*, lower medullary plate; *a. l. ol.*, anterior fibrillar layer of the lower optic lobes; *gl. pl.*, glomerulated plate of the lower optic lobule; *pf. lol.*, posterior fibrillar layer of the lower optic lobule; *l. o. l.*, lower optic lobe; *cer. gang.*, cerebral ganglion.—After Saint Remy.

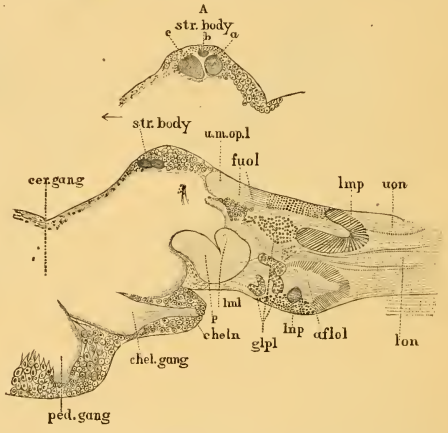

FIG. XIII.—Longitudinal (sagittal) section of the same, passing through a plane situated near the junction of the outer third with the middle third of the brain. *str. body*, stratified body; *u. m. o p. l.*, upper medullary mass of the upper optic lobe; *f. u. o. l.*, fibrillar layer of the upper optic lobule; *u. o. n.*, upper optic nerve; *l. o. n.*, lower optic nerve; *l. m. p.*, lower segment of the lower medullary plate; *l. m. l.*, lower medullary mass of the lower optic lobe; *p*, head of the lower medullary mass; *chel. n.*, cheliceral nerve; *chel. gang.*, cheliceral ganglion; *ped. gang.*, ganglion of the pedipalp.—After Saint Remy.

A. Part of a transverse section through a plane near the middle of the brain, to show the stratified body (*str. body*). *a*, principal plate of the anterior segment of the stratified body; *b*, accessory plate of *a*; *c*, posterior segment of the stratified body.—After Saint Remy.

I have been unable to detect any trace in the brain of Limulus of the posterior stratified body (Fig. XII–XIV, *str. body*) which is regarded by Saint Remy as the homologue of the "pedunculated body" of insects. Neither does M. Viallanes refer to any organ similar to that discovered by Saint Remy.*

The position of this organ and its structure should be noticed. Both in spiders and the scorpion it has nearly the same situation as in insects, being placed in the uppermost region of the head in a lobe-like swelling projecting above the general surface of the brain. In the side view of the scorpion's brain (Fig. XIV *str. body*) it is seen to be somewhat trilobate and divided into an

* But in his final paper, p. 449, he very briefly states that this organ, "although modified, is likewise recognizable in the Arachnids, where it has been described by M. Saint Remy under the name of *organe stratifié*."

upper and lower portion, but without any stalk passing downward into the central portion of the brain.

Dr. Saint Remy describes this body at length under the name *organe stratifié postérieur*, and says that it is situated on the very salient posterior and upper border of the brain, forming a prominent projection above the punctuated mass of the cerebral lobes. It comprises a principal medullary portion and a cellular covering. It is formed of parallel alternate clear and obscure bands.

That this organ is apparently not homologous with the mushroom bodies of insects appears to be proved by the fact that it is single, not a paired organ.

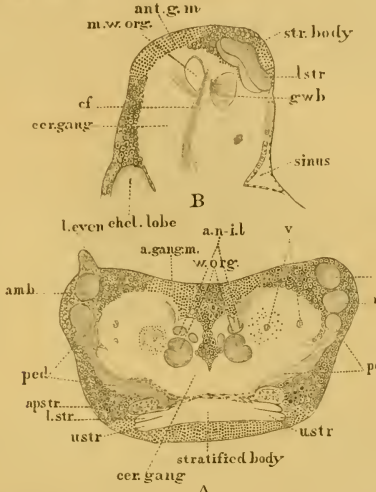

FIG. XIV.—A, horizontal section passing through the upper part of the brain of the scorpion (*Buthus occitanus* Amorx.) through the lower optic lobe or ganglion. *cer. gang.*, cerebral ganglion; *l. eye n.*, lower eye nerve; *amb*, anterior medullary ball of the lower optic ganglion; *m. b.*, middle medullary ball of the same; *ped.*, common peduncle of the optic lobules; parts of the stratified organ or body; *l. str.*, lower segment; *u. str.*, upper segment; *apstr*, anterior plate (lame) of the upper segment of the same; *a. gang. m.*, anterior ganglion-mass; *an. i. l.*, antero-internal lobule; *w. org*, principal medullary mass of the anterior segment of the wallet-shaped organ; *v*, vessel (artery); *B*, longitudinal (sagittal) section of the same passing through the union of the lateral third with the middle third of the brain. Very young individual. × 53 diams.. *g. w. b.*, principal glomerulated mass of the posterior segment of the wallet-shaped organ; principal medullary mass of the anterior segment of the wallet-shaped organ; *ant. g. m.*, anterior ganglion mass; *chel. lobe*, ganglion innervating the first pair of appendages; *c. f.*, commissural fascia.—After Saint Remy.

In the scorpion (Fig. XIV, *str. body*) the stratified body differs somewhat from that of spiders, but is essentially the same. "But the most interesting feature about it," says Saint Remy, "is the relation which exists between this organ and the optic lobe by the medium of the common peduncle." Although the stratified body of Arachnida is described and figured as unpaired, yet in deference to the opinion of Saint Remy I provisionally accept his view that it is the homologue of the pair of pedunculated bodies of insects. I may add that it is a matter of surprise to me that M. Viallanes does not dwell more on the remarkable differences between the brains of Limulus and of the Arachnida, particularly the great differences between the mushroom-bodies of Limulus and their homologues in Arachnida, since he adopts the opinion that Limulus is an Arachnidan. On the other hand these striking differences in the morphology of the brain tends to my mind to furnish additional proof that Limulus is the representative of a different class of Arthropods.

Another organ which is characteristic of the scorpion's brain we have failed to detect in that of Limulus, nor does Viallanes mention it. Saint Remy thus describes that of the scorpion:

The structure which, for want of a better name, we shall designate under the name of *wallet-shaped organ* (*organe en bissac*) to recall its general form, occupies the internal and middle part of the cerebral lobe. It comprises two segments united by a much smaller middle portion in the form of a neck (p. 224).

Still another organ also present in the scorpion's brain which we have not found in the brain of Limulus, and which is not mentioned by Viallanes, is the *olivary body*. It is situated in the posterior region of the cerebral lobe below the wallet-like organ near the median line; it is an olive-shaped mass of dense punctured substance and situated obliquely.

Considering, then, the fact that the deutocerebrum or its homologue is in Limulus separate from, where in Arachnida it is fused with the brain; also the differences in the shape of the cerebral lobes, the immense development of the ruffle-like plates or masses of small chromatic ganglion cells forming the pedunculated or mushroom bodies; the small number of large ganglion cells; the absence of the wallet-shaped and of the olivary organs found in the brain of scorpions, and

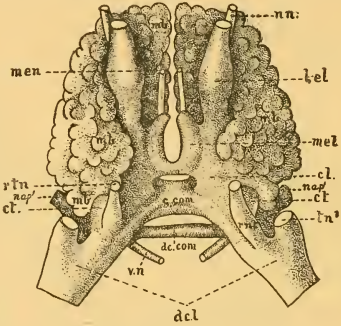

Fig. XV.—Brain of *Limulus polyphemus*, drawn by Viallanes, from a model in relief of the brain of Limulus, made of wax, seen from the dorsal aspect, the neurilemma having been removed. *l. e. l.*, lateral-eye lobe; *m. e. l.*, median-eye lobe; *m. e. n.*, median-eye nerve; *n. n.*, nerve passing to the neuropore of Patten (*fossette sensitive* Viallanes); *m. b.*, *m. b.*, *m. b.*, *m. b.* lobules of the mushroom or pedunculated body; *c. t.*, cerebral tubercle in part, giving rise to the stalk of the mushroom body; *c. l.*, cerebral lobes; *r. t. n.* and *r. n. t.*, recurrent tegumental nerve; *n. a. p.*, nerve of first pair of appendages (cheliceral nerve of Viallanes), *c. com.*, cerebral commissure; *d. c. com.*, deutocerebral commissure; *d. c. l.*, deutocerebral lobes; *v. n.*, root of visceral or sympathetic nervous system.—After Viallanes.

It is to be observed that the median-eye ganglia are not correctly represented by the model, the horseshoe shaped mass simply representing the fibres. See my Pl. VII, Fig. 1. This empty median oval space is, in nature, filled with large and small ganglia cells, and the roots of the fibres originating from them.

the absence of the peculiar medullary plates present in the optic lobes of spiders, we see that while the brain of Limulus is in most respects simpler, it also presents noteworthy differences from that of the Arachnida.*

* Since this paper was put in type, and a few days before obtaining the proof, I received the Annales des Sciences Naturelles, Zoologie, Nos. 4, 5, 6 for March 10, 1893, containing M. Viallanes' final paper on the brain of Limulus.

The account of the internal structure of the brain is brief, occupying but five pages, and ends with an "*Aperçu général de l'organisation du système nerveux des Articulés.*" The article is illustrated with two folding plates. Only two actual sections of the brain of Limulus are represented. One (Pl. 10, Fig. 17) represents a horizontal section passing through the lateral-eye ganglion ("ganglion optique") of one side, and the other (Fig. 18) of a horizontal section lower down passing through the stalk of the pedunculated body.

This last figure clearly shows what my sections has failed to do, except partially, the well-defined stalk of the mushroom, or pedunculated body, and shows that what in the first place I had described as the "nucleogenous bodies," are lobules or branches of a pair of organs probably homologous with those of insects. This leads me to accept M. Viallanes' view of the homology of these extraordinarily developed organs with the two mushroom bodies of insects. In accordance with this view I have corrected the text of the present article. Viallanes has also pointed out and drawn the chiasma of the median eye, structures which I had failed to see; and he shows that the basal

XI. NOTES ON THE EMBRYONIC DEVELOPMENT OF THE BRAIN AND VENTRAL CORD. PLATES XVIII AND XIX.

The general morphology of the brain of Limulus can not be with certainty fully worked out without a knowledge of the embryology of the nervous system, especially of the relations of the neuromeres of the head and of the changes which take place in the relative arrangement of these neuromeres, and of the lobes formed by them during the development of the parts of the head in the later embryonic stages.

Also, the mode of development of the ruffle-like masses of chromatic or aprotoplasmic ganglion cells will have to be studied during the period of larval life succeeding the first molt, and before the body becomes, say, about an inch in length without the caudal spine. With the results of Prof. Patten's work we are not satisfied, as we feel by no means sure that his diagrams in his Figs. 7, 8, 9, and 10, however ingenious, are in all respects reliable, and are confident that no more than a single pair of median eyes actually exist in nature. We have found no traces of a second pair of median eyes, nor has Kishinouye detected them. Until, then, Prof. Patten publishes his observations in full we should prefer to wait before entirely accepting his diagrammatic figures and some of the views expressed in his paper.

The most important observation on the development of the brain of Limulus are those of Mr. Kishinouye, who seems to have paid special attention to this subject. He states:

> The lateral halves of the nervous system develop independently of each other. Each half of the brain with its corresponding ventral nerve cord is produced as a continuous long cord of epiblastic thickening just inside the base of the appendages (Figs. 12–14). It is easy, however, to distinguish the brain from the ventral nerve cord. When they are first formed, the former is very much broader than the latter, occupying almost the whole of the segment of the cephalic lobe, while the ventral nerve cord occupies only about one-third of the breadth of each appendage-bearing segment (Fig. 12).

Kishinouye then describes the "paired small invagination" which appears in the lateral part or margin of the brain, and another paired epiblastic invagination along the anterior internal corner of the margin of the brain. These cephalic invaginations are, however, very shallow, and disappear before the separation of the nervous system from the epiblast takes place.

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portions of these lobes belong to the lobes in question. I had regarded them as lateral lobules of the cerebral lobes, but now accept Viallanes' view as to their nature.

M. Viallanes has also succeeded better than myself in making a wax model of the interior structure of the brain, giving a dorsal, ventral, and a sagittal view, and I reproduce his figure of the model of the dorsal view as it shows better than I could do the relation of the optic and ocellar lobes to the cerebral lobes. I am able to confirm the accuracy of his work, and am glad to bear tribute to the skill and patience he has shown in working out the structure of the brain of this animal. On pages 449 and 450 he discusses the organization of the brain of Limulus and of Arachnids. He very briefly (in three lines) states his belief that the two pedunculated bodies of Limulus are the homologues of the "striated organ," of Arachnids, but does not enter into details, or attempt to show how the two bodies in Limulus can be homologized with the single stratified organ of Arachnids. Neither does he refer to the very great differences between the size and shape of the cerebral hemispheres of Limulus and Arachnids, and to other differences to which I have drawn attention. I can not agree with M. Viallanes that the brain of Limulus is the exact homologue of the brain of Arachnides; I hold that the "deuto cerebrum" does not form a part of the brain proper, that it is not fused with it, that it is post or at least paracesophogeal, since it innervates the first pair of appendages, and this shows that Limulus is in this respect more primitive than the Arachnids. The fusion of what were originally distinct ganglia (see my Pl. XVIII, Fig. 7) has never gone on so completely as in the Arachnids. Hence the brain characters, together with the absence of the urinary tubes, and of tracheæ, and the presence of branchiæ, besides the shape of the six pairs of cephalic appendages and the large median eyes, as well as other minor characters, are sufficient in importance to make Limulus the representative of a class by itself, with which the trilobites should be associated.

I may be allowed to add that M. Viallanes' contemptuous critique of my first very imperfect account of the brain of Limulus, published in 1880, is a grain harsh and unfair, since before writing it he must have had in his hands my brief abstract of the present paper published in the *Zoologischer Anzeiger* for April 20, 1891, and a copy of which I mailed to him. Even in my first account published in 1880, while I incorrectly stated that the brain was unsymmetrical, I called attention to and figured the "nucleogenous bodies," and pointed out their enormous development. To my discovery of these important structures M. Viallanes condescends to make no reference; I had also pointed out the differences between the large ganglion cells and the small aprotoplasmic ones, or the "nuclei" composing the nucleogenous bodies. I did not point out clearly the limits of the median and lateral eye lobes, and those of the cerebral lobes, because in my osmic acid preparations (made in 1879) they are not shown so well as in those stained with carmine.

He then adds:

The part of the brain formed by the external groove becomes the optic ganglion of the lateral eyes, as in the case of the spider. The optic ganglion of the median eyes is produced from the epiblastic thickening forming the united mouth of the invagination for the median eyes (Fig. 69, g. med. *e.*, *our* fig.).

The brain, which was almost circular in its outline, as its height was almost equal to its breadth (Figs. 12, 34) becomes afterwards semicircular (Fig. 13), later still sickle-shaped (Fig. 14), and shortly before hatching almost straight (Fig. 69). This is caused probably by the peculiar development of segments. All the segments seem to develop most vigorously at the line midway between the ventral and dorsal median lines, *i. e.*, all the segments have their greatest antero-posterior extension on this line, and become shorter and converge, like the frame pieces of a folding fan, toward both the ventral and dorsal median lines. Therefore the external ends of the brain are pushed anteriorly by the growth of the succeeding segments. About two weeks before the hatching of the embryo the brain proper becomes divided into two transverse portions by a constriction (Fig. 69). Thus the brain of Limulus may be divided into four parts; the ganglion of the median eyes, the ganglion of the lateral eyes, and the anterior and posterior portions of the brain proper. These four parts are arranged in three transverse rows. The anterior row is occupied by the two pairs of the optic ganglia, the middle row by the anterior portion of the brain proper, and the posterior row by the posterior portion of the brain proper (Fig. 69).

We have quoted Kishinouye's observations at length, because they clearly and simply explain as no one had done before, the mode of origin of the ganglia of the brain. In Prof. Kingsley's last article little is said upon this subject, his attention not having apparently been directed to the development of the ganglia of the brain.

My own imperfect observations confirm those of Kishinouye, but were made on a stage apparently before that represented by his Fig. 13, and after that of his Fig. 12. The legs in my embryos had not yet become divided at the ends into claws, while there were three pairs of abdominal appendages. It also appears to be of a later stage than that represented by Kingsley in his Fig. 32, though the ambulatory or cephalothoracic legs of my embryos seem less advanced in development. In my embryos also the neuroblasts had disappeared, though I made repeated attempts to discover them. Kishinouye states that "they disappear when the ventral nerve cord is divided into ganglia and begins to be separated from the epiblast" (p. 73).

Kingsley's Fig. 32 well represents the cerebral and lateral-eye lobes; but his sketch does not give a clear view of the median-eye ganglia, which in my specimens were distinctly separated from the lateral-eye ganglia and the cerebral lobes, and were somewhat conical in shape. I reproduce on Pl. XVII, some camera sketches of the lobes of the brain seen in the stage represented by the shaded Fig. 1, the mouth at this time being situated between the first pair of appendages. The eggs were taken from the vicarious chorion or deutovum, and stained from two to three minutes in alcohol cochineal, so as to bring out quite clearly the ventral plate and parts of the germ, which had been freshly killed. All the figures on this plate were made from a single embryo.

In Fig. 2 the relation of the lobes is shown by a camera sketch made in direct sunlight. The lateral-eye lobes or ganglia are seen to be distinct from the cerebral ganglia (*cer. gang.*), and in front of the former are the triangular median-eye lobes. I could not detect any traces of a second pair of median-eye lobes or median eyes; and, as already stated, I am led to think that Patten was mistaken in supposing that they exist. Just above the mouth (*m*) is a shield-shaped or somewhat triangular convex area, which is not figured by Kingsley, and of the nature of which I am doubtful, unless it be the rostrum or upper lip. It was seen very distinctly and at different times. In front of it is a small depression (probably the neuropore of Patten), and a larger one is seen in front of the union of the cerebral lobes.

Fig. 3 is another sketch made from the same egg, showing the same parts from a side view. In this figure there is represented an irregular depression between the second pair of abdominal appendages, which, however, was not always seen. Fig. 3*a* is a camera sketch of the head of the embryo seen from one side, the left side being the part most distinctly seen.

The neuromeres were distinctly developed, a pair to each pair of appendages. In the abdomen three pairs were distinctly seen, as represented in Figs. 4, 5, and 6. I was able to see them very distinctly at different times. In Kingsley's Fig. 32 no abdominal neuromeres are represented. His figure may represent a later stage, though I hardly understand why he does not represent the third pair of abdominal legs, which I repeatedly saw, my Fig. 5 being a careful sketch of those of the right side made in direct sunlight. In Fig. 6 the vent or proctodæum was observed, situated between the last two neuromeres.

Thus far our results tend to prove that there are in the embryo three pairs of prestomial brain ganglia: (1) the median-eye ganglia, (2) the lateral-eye ganglia, and (3) the central or cerebral ganglia with their outgrowth, the mushroom bodies. We have been able to detect these in the brain of the adult Limulus, and have been unable to find any other important fundamental structures in the brain proper.

The changes which the different lobes of the brain undergo in late embryonic and in early larval life have in part been described by Dr. Patten, and briefly by Kishinouye, but need further elucidation. The problem is a difficult one, and we need material for it, which no observer has yet apparently had, viz, specimens after the first molt. In the trilobite stage, as seen in Kishinouye's Fig. 45, reproduced on this page, the medulla or central white fibrous portion (*f*) is differentiated from the ganglionic cortex (*g c*), but his figure does not include the optic ganglia.

FIG. XVI.—The brain of Limulus in the trilobite stage.—After Kishinouye.

Pls. XVIII and XIX represent sections of the brain of the larva. So far as I have been able to make out from my sections, the cerebral ganglia grow rapidly in size, the median-eye lobes sink in below the level of the upper side, the lateral-eye ganglia overlying them and forming the two lateral superior swellings of the upper surface of the brain. The median-eye lobes are partly coalesced, and the nerves proceeding from them grow together on leaving the brain, only separating at the median eyes. At this period the mushroom bodies have not yet been developed.

XII. Observations on the development of the abdominal appendages, and of the gill-sacs or branchiæ. Plate XX.

The unusual amount of interest attached to Limulus, and the great diversity of opinion which has been, and still is, held by zoölogists in regard to its affinities, seems mainly due to the fact that this animal is a composite or generalized type, with most important features peculiar to itself and to its class; it also has some points of resemblance to the Phyllopod Crustacea, which are perhaps the most generalized and primitive group of Crustacea, unless the Phyllocarida be excepted. On the other hand its embryology and some anatomical characters ally it still more closely with the Arachnida, so much so that it seems, contrary to our earlier views, not unreasonable to suppose that the two groups may have had a common origin; though the Merostomata, with the Trilobites, were with little doubt developed much earlier than the Arachnida, the class Podostomata being nearer their vermian ancestors than the Arachnida.

When we take into account the Cambrian Paradoxides and the Silurian Arethusina with their very numerous (about 30) segments, and what we know from Walcott's researches of the probable nature of the legs of Calymene, Ceraurus, Acidaspis, etc., we can see that the independent evolution of such Trilobites from some branchiate Annelid was quite as natural and probable as the derivation of some Protophyllopod, or Protophyllocaridan Crustacean from a branchiate Annelid worm, and that it probably took place at an earlier geological epoch.

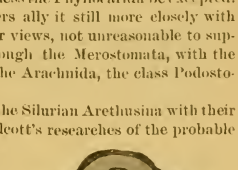

FIG. XVII.—Restored section of the thorax of a Trilobite (Calymene). *c*, carapace; *ex*, endopodite; *en*, exopodite, with the gills on the epipodial or respiratory part of the appendage.—After Walcott.

Examining Walcott's restoration of the underside of *Calymene senaria*,* as well as his figures of actual sections, we notice a great uniformity in all the appendages from the head to the end of the pygidium, which is paralleled by that of the limbs of Phyllopods. True, in the Trilobites there were no functional antennæ and mouth-parts, and all the limbs, both of the head, thoracic region, and of the pygidium, were similar in shape, being cylindrical and short, thus fitted for walking, and bore dorsal branchiæ.

The branchiæ, says Walcott, as found in Calymene, Ceraurus, and Acidaspis have three forms. In the first form they divide a short distance from the attachment to the basal joint of the leg and

* Bulletin Museum Comp. Zoöl., VIII, Pl. VI, Fig. 1, 1881.

extend outward and downward as two simple, slender tubes or ribbon-like filaments. In the second form they divide in the same manner, but the two branches are spirals. (See Fig. XVII.)

The third type, which is apparently confined to the anterior segments of the thorax, is figured in his Pl. III, Fig. 2. Here there was a series of at least 17 thin leaves arranged from above

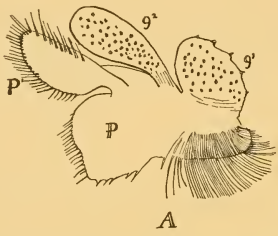

FIG. XVIII.—A, a leg of *Branchinecta lindahli* (from 10th pair); g^1, g^2, gills; *P*, P^1, the two parapodium-like lobes, comparable with those of the annelid Lyarete (B), *dc*, dorsal cirrus, acting as a gill.

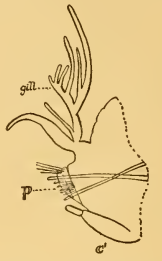

FIG. XIX.—Leg or parapodium of *Eunice conglomerans*, with a branched gill and the ventral cirrus (c^1) divided into two joints.—After Ehlers.

downwards, not spiral but flat, somewhat as in Limulus, and radiating vertically from a jointed epipodite or branchial arm. Thus as in forms like Calymene, Asaphus, Bronteus, etc., all the limbs behind the mouth-region were cylindrical, ambulatory, and branchiferous, but those of the pygidium were not broad and flat and adapted for swimming, as in Limulus. Thus the Trilobites were less differentiated and more closely allied to the Annelid type than the Eurypterida and Limulus. It thus seems probable that the three great groups of Arthropoda had each an independent origin from the higher worms, or from extinct forms like them. The insects, with the Myriopods, were independently evolved from some Chætopod worms of unknown affinities by way of Peripatus; the Podostomata* by an independent path also originated from a true branchiate Annelid, while the Crustacea with little doubt, as generally conceded, arose from some Annelid-like form; perhaps one with dorsal cirri acting as branchiæ, like those of *Lyarete braziliensis*, figured by Ehlers (Mem. M. C. Z., 1887), these being remarkably like those of Branchipus and other Phyllopods.† (Fig. XVIII, B.)

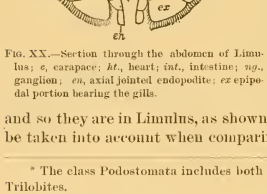

FIG. XX.—Section through the abdomen of Limulus; *c*, carapace; *ht.*, heart; *int.*, intestine; *ng.*, ganglion; *en*, axial jointed endopodite; *ex* epipodal portion bearing the gills.

It is also to be borne in mind that in the trilobites, the branchiæ were dorsal though lying under the dorsal wall of the body, and attached to an epipodal division of the limbs, and so they are in Limulus, as shown by our Fig. XX. This dorsal position of the gill-plates should be taken into account when comparing them with the book-leaves of Arachnids.

* The class Podostomata includes both the Merostomata, of which Limulus is the living representative, and the Trilobites.

† The problem of the derivation of the jointed limbs of Arthropods from the soft non-jointed Annelid parapodium is paralleled by that of the origin of the limbs of the higher vertebrates from the fins of fishes. The limbs of Arthropods are divided into a few or many leverage systems, represented by segments or joints. There are all grades of Arthropod limbs, from the unjointed parapodia-like limbs of Phyllopods, which are most Annelid-like, to the imperfectly jointed swimming legs of the Nauplius of various Crustacea, and to the abdominal legs of Malacostraca, up to the ambulatory legs of Decapods and of terrestrial tracheate Arthropods. These varieties of shape can be explained by adaptation to changed conditions resulting from a change from an aquatic to a terrestrial life, or from simply swimming to walking on the bottom or to burrowing in sand and mud. On the other hand the appendages of Syllid worms are often jointed, and in Eunice (Fig. XIX) and Polynoe, the lower division of the parapodium consists of two joints.

In the Merostomata there must have been a considerable diversity of shape and mode of attachment. Fortunately we know something of the form of those of Slimonia, an Eurypterid. Dr. Henry Woodward has described and figured them in his valuable Monograph of the British Merostomata (Pl. XIX, Figs. 3 and 4, p. 115). Similar ones in *Pterygotus bilobus* have been described and figured by him. (Pl. XII, Fig. 1*d*). Woodward thus describes those of Slimonia:

They appear to be arranged in linear series and were attached in single or double rows to the under surface of the body by their upper end, whilst their lateral and lower rounded leaflike borders were freely bathed in the fluid medium in order to oxygenate the blood.

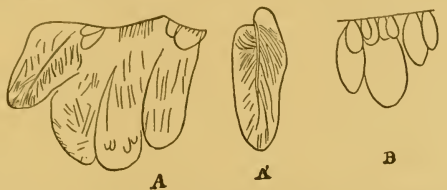

FIG. XXI.—A, gill-leaves of Slimonia; A', a separate one showing the "vascular striæ;" B, those of Pterygotus, both large and small. After Woodward.

These leaflike appendages are highly vascular; they are about two inches in length and three-fourths of an inch broad, but they vary in size, having probably been largest near the center of the body, becoming smaller as they approached the sides (p. 115, 116).

These delicate membranous plates in Pterygotus differ in form from the corresponding organs in Limulus; but there is no doubt they occupied the same relative position. In Limulus the vascular striæ are parallel to the circumference of the lamellæ; in Pterygotus they appear to have branched and subdivided from the center to the margin of the plate, becoming finer and more numerous toward the border* (p. 68).

HISTORY OF OPINION AS TO THE HOMOLOGY OF THE GILL-BEARING ABDOMINAL LEGS OF LIMULUS WITH THE BOOK-LUNGS OF ARACHNIDA.

Nothing was said of the mode of origin of the book-lungs of the Arachnida until the appearance of Metschnikoff's Embryologie des Scorpions (1870). He states: "The second pair of abdominal appendages are transformed into the comblike organs, while the appendages of the other segments of the abdomen totally disappear." *In the place of the four pairs of the same* (*not, however, developing from these*) *appear eight gill-pouches* (Kiemenlöcher).

Further on Metschnikoff describes the development of these lungs:

The lungs form invaginations of the chitinous layer which are situated directly under (*dicht unter*) the segment appendages of the four abdominal segments (Taf. XVI, Fig. 12 *p. a.*). They appear first in the form of cup-shaped sacks which open though a broad mouth. After a further development of the lung-sacks, accompanying which there is an atrophy of the abdominal segments (with the exception of the second pair [of appendages] of the same), they become more roomy and deeper. But first in the latest embryonal stages (Taf. XVI, Fig. 14, from the ventral, Fig. 15, from the dorsal surface) there grows up out of the dorsal part of the lungs a blind tubular passage, whereby also within the lung sacks begins the formation of the leaves. The external gill-opening becomes by this time considerably smaller. The walls of the embryonal lungs consist of a cylindrical epithelium on whose inner side becomes separated a fine cuticula. Moreover, here and there on the outer surface of the lungs are certain groups of cells which evidently belong to the mesoderm.

Although Metschnikoff carefully describes and figures the mode of origin and process of invagination of the book-lungs he does not entertain the idea that they are modifications of the transitory abdominal appendages under which they arise.

* From a taxonomic point of view too much dependence must not be placed on the position and arrangement of the gills or respiratory organs in any class. For example, in Scutigera, a Myriopod, the tracheæ are grouped into structures like book-leaf tracheæ placed in a row down the median dorsal line. These lungs project into the pericardium and thus aërate the blood. (See Sinclair, "A new mode of respiration in the Myriapods," Ann. and Mag. Nat. Hist. March, 1892. See also Voges's Das Respirations-System der Scutigeriden, Zool. Anzeiger, V, 1882, pp. 67-69. Also E. Tömösváry, Ueber das Respirationsorgan der Scutigeriden (Vorläufige Mittheilung) Math. Naturw. Ber. Ungarn I. Bd., p. 175-180, Taf. 4, Fig. 1-4, 1882-'83).

In 1871 E. Van Beneden first suggested the homology between the branchial limbs of Limulus and the lungs of Arachnids. (C. R. Soc. Ent. Belgique, 1871.) He afterwards (1882) reaffirmed this view. In his second paper he derives the Arachnida from the Pœcilopodes (Limulus).

Salensky, according to the abstract in Jahresb. üb. Anat. u. Phys., as early as 1871, stated his belief that, in the spider whose embryology he studied, the third and fourth pairs of provisional abdominal appendages became spinnerets, while the two anterior pairs developed into lungs.

The following is a translation of what is said by the reporter:

The first pair of abdominal legs are transformed into lungs; the special details of this process of transformation are not wholly understood by the author. The second pair of abdominal legs become flatter, broader, and modified into a vascular sinus, in which the cells of the inner germ-layer are changed to blood-corpuscles. The third and fourth pairs of abdominal legs form the germs of the spinnerets; between the third pair arise two new hook-like projections becoming a third pair of spinnerets (p. 324).

In his valuable Recherches sur l'Anatomie des Limules (1872) A. Milne-Edward thus refers to the homology between the gills of Limulus and the lungs of the scorpion:

Les membres abdominaux des Limules sont, comme on le sait, élargis en forme de lames, et ceux de la première paire, tout en servant d'opercule pour clore en dessous la fosse respiratoire, portent les orifices génitaux, tandis que les membres des quartre paires suivantes donnent naissance à autant de branches multifoliées. Chez les scorpions, il n'y a rien qui rappelle les appendices operculiformes dont je viens de parler, et les orifices génitaux sont situés un peu plus en avant à la partie sternale de la régien thoracique; mais il y a une grande ressemblance entre les cinq paires de fausses pattes branchiales des Limules et les quatre paires de poches pulmonaires des scorpions; il y aurait même presque identité si, chez des Limules, ces appendices, au lieu d'être libres par leurs bords latéraux aussi bien qu'en dessous, contractaient avec les parties voisines du test des adhérences, de façon à ne laisser d'ouverture que sous leur bord inférieur, et si les feuillets branchiaux de ces animaux, au lieu d'être imperforés, se creusaient d'une cavité accessible à l'air, à peuprès de la même manière que les fausses pattes branchiales des Tyles et des Porcelliens se creusent de poches pulmonaires. Si la forme organique réalisée par les Limulus, au lieu d'être appropriée à la vie aquatique, s'adaptait à la respiration aérienne d'une manière analogue à ce que nous savons exister chez certains représentants terrestres du type dont dérivent les Crustacés isopodes à respiration aquatique, il n'y aurait donc, sous ce rapport, aucune différence importante entre ces deux sortes d'animaux articulés (p. 56).

Balfour, in his "Notes on the development of the Araneina" (1880), does not refer to the book-lungs or to their mode of origin. In speaking of the four pairs of rudimentary abdominal appendages, he remarks:

The four rudimentary appendages* have disappeared, unless, which to me seems in the highest degree improbable, they remain as the spinning mammillæ, two pairs of which are now present.

Balfour's observations were made on *Agelena labyrinthica*.

In his essay entitled "Limulus an Arachnid," Lankester, in 1881, following A. Milne-Edwards, adopts the homology of the book-lungs of the Arachnida with the branchial legs of Limulus. He was apparently ignorant of, or had overlooked, Salensky's opinion that the last two pairs of embryonic abdominal appendages of the spiders become the spinnerets. Lankester remarks:

When we examine the sternal area of the segments of Limulus which carry lamelligerous appendages, we find that, although the integument is mostly soft and flexible, yet there are small sclerites present, *and in fact stigmata or apertures leading into pits corresponding to the stigmata of the pulmonary sacs of Scorpio.*

These "muscular stigmata" are then described in detail, followed by a hypothesis of the mode of origin of the book-lungs from branchiferous limbs like those of Limulus, which was afterwards abandoned by the author. We opposed this hypothesis in a critique of Lankester's paper (Amer. Naturalist, April, 1882) and suggested a difficulty in the acceptance of this view when the gill-plates of the Eurypterida are taken into account, these being arranged somewhat like the teeth of a rake. Lankester also expresses the opinion that the Arachnida through the scorpions were derived from the Merostomata, and that it is not possible to place the scorpions and the Merostomata in separate classes (p. 82).

MacLeod (1882) regarded the lungs of the scorpion as the homologues of the gills of Limulus, but explained the mode of transformation of gills into book-lungs differently from Lankester.

He regards the two structures as homologous and explains the transformation of the Limulus gills into lungs in the following way: The lengthening of the abdomen of Limulus had the result that the abdominal gill-bearing limbs were no longer covered; hence a part of each gill-bearing limb coalesced with the integument of the abdomen and then respiratory cavities came to exist. When this kind of Limulus became adapted to a terrestrial life, the gill-leaves, no longer supported

*He undoubtedly meant to say four *pairs* of rudimentary appendages, as he figures them (Figs. 5 to 8*a*, 8*b*).

by the water, must have simultaneously become soldered by their edges to the walls of the gill-chamber.

For our earliest information regarding the mode of development of the lungs of spiders we are indebted to Schimkewitsch (1885). He states:

Balfour has shown* that the tracheæ and lungs of Araneina are formed by the invagination of the ectoderm. I am unable to confirm this observation. In the embryo of *Lycosa saccata*, before hatching, the tracheæ are represented by a principal trunk from which arise four secondary branches. Their wall is formed of the epithelial ectodermic layer lined by a homogeneous internal coat and covered by an external coat containing nuclei of mesodermal origin (V, chap. III). In this same stage the structure of the lungs is very interesting (Pl. XXII, Fig. 1, *pm*). A. Milne-Edwards and J. MacLeod have endeavored to prove the homology of the lungs of Arachnida with the gills of Limuli. The lungs of the embryo of *Lycosa saccata* consist of true tracheæ arranged in bundles; the principal trunk (Pl. XXII, Fig. 1), which opens outward by the stigmatic orifice (*st*), divides into five secondary branches. The epithelial layer of these last is represented by flattened cells. The secondary branches, flattened from above downward, enter the cavity surrounding the lungs, and in the spaces between these are to be seen the blood corpuscles. Thus the embryonic lung consists of a trachea arranged *en faisceau;* the only difference to be noted is the absence of the external tunic, which I have not observed, either on the lung of the embryo or on that of the adult (p. 561).

In the following year, in his "Les Arachnides et leurs Affinités" (1886), he reiterates this view.

In the same year, Locy, in his "Observations on the development of *Agelena nævia*," gives a still more complete account of the mode of origin of the lungs of spiders, with excellent figures. He states that the lungs arise as a pair of extensive invaginations at about the same time as the proctodæum. "In sagittal sections of early stages the lungs appear as oblong plates of cells, the large oval nuclei of which are arranged in parallel rows." The flattened sacs are hollow and divided at intervals by 2-cell columns, the interspaces sometimes containing blood corpuscles. The details are mostly histological and the author does not enter into any morphological comparison with the book-lungs of Limulus, but nothing is said contrary to the view that the lungs are a bundle of tracheæ.

In his paper "On the origin of vertebrates from Arachnids" (1890), Patten refers to the chitin-lined tubes of the scorpion, "which serve for the support of muscles." These, as we understand them, are the "muscular stigmata" of Lankester and occur in insects as well as in Arachnida and Podostomata, as we have observed them in a specimen of Asaphus as well as in Limulus. As Patten remarks: "The chitinized tubes are comparable with the three or four pairs of tracheal invaginations which in insects give rise to the tentorium." He then adds:

I regard the lung-books of scorpio and the chitin-lined tubes described above as belonging to the same category, for after careful study I have found nothing to indicate that they arise as modifications of rudimentary abdominal appendages (p. 355).

In 1885 Lankester discards his first hypothesis, which he regards as "overstrained," and replaces it by a second "perfectly simple" one.

In his notes on the embryology of Limulus (1885) Kingsley describes the early stages of the abdominal limbs and discusses at some length their homology with the "pulmonary books" of Arachnids, and he admits its general validity, though not ready "to follow all of Prof. Lankester's intermediate steps, nor those of MacLeod." His hypothesis and figures are ingenious and more simple than those of Lankester. As he remarks:

As I have mentioned above, the process of formation of the gill-leaves is largely by a process of outgrowth, but there is also a slight ingrowth, especially noticeable at the distal portion of the appendage. This, however, disappears with growth, but is very noticeable in all my sections. To transform the gill of Limulus into the lung of Scorpio it is only necessary that, together with the sinking of the whole organ, as described above, the inpushings of the integument to form the lamellæ should be exaggerated and the outgrowth correspondingly decreased. On Pl. XXXVII, Figs. 18 to 20, I have diagrammatically illustrated the steps in the process, the gill-leaves being few in number to secure clearness. In 18 we have the typical condition found in Limulus, one appendage being shown half in section and half in perspective. In 19 we have an intermediate condition, when, as suggested above, the animal was leaving the water and seeking a terrestrial life. Here the gill-bearing appendage (*ga.*) is partially sunk in the surrounding tissues to secure protection. The same causes would also tend to produce a similar change in the gill leaves (*gl.*) and they would also tend to be formed rather as ingrowths than as protruding processes. This change in structure would be the more readily effected on account of a change of the medium of respiration. A gill needs either to project into the water or to have some means of instantly changing the fluid which bathes it. An organ for aërial respiration, on the other hand, is not so restricted in its position, since the air is more fluid and more elastic and hence more readily changed. Another advantage to the animal resulting from the change is that the oxygen is thus brought nearer to the tissues requiring it.

* I can find no reference in Balfour's memoir to this subject.

In Fig. 20 we have a diagrammatic representation of the pulmonary sac of the Arachnids. The appendage (*ga.*) has now become sunk in the body and the hole through which it passed is the stigma (*stg.*). The gill-lamellæ have entirely disappeared and the pulmonary ones (*pl.*) have taken their place. The process here described is different from that imagined by MacLeod. It accords more with the development of the gills in Limulus and avoids the necessity of union of the gill laminæ and the expansion of the sternum.

But the most convincing and direct proof of the conversion of a portion, not all, of the temporary embryonic abdominal limbs of the Arachnids into lungs has been afforded us by the statements and figures of Kishinouye in his essay "On the development of Araneina," 1890. As will be seen by the following extract, the view also suggested to us by Metschnikoff's description and figure is that the *entire appendage is not converted into the book-lung.* Kishinouye also states unqualifiedly that the third and fourth pairs of abdominal appendages are transformed into spinnerets. His drawings (Fig. 34) directly confirm this and establish the truth of Salensky's supposition.

In the basal part of the first abdominal appendage of each side there arises an ectodermic invagination, whose opening faces away from the median line. It is neither deep nor spacious, but is a little pocketlike invagination. This is the beginning of the lung-book.

The development of this organ, briefly stated, is as follows: Of the wall of the invaginated pocket, that which faces the distal end of the appendage is much thicker than the opposite wall, filling the interior of the appendage. The cells composing it become after a while arranged in parallel rows (Figs. 34 and 47). Each two of these parallel rows adhering together produce the lamellæ of the lung-book. The external epithelium of the appendage which cover these lamellæ becomes the operculum of the lung-book after it is depressed in height. Judging from figures (Figs. LXXIX and LXXIX') given in his essay "On Insects and Arachnids," Bruce seems to have mistaken the caudal prominence of the early period of this stage (see my Figs. 24–28) as the operculum of the lung-book. According to him the abdominal appendage is invaginated to form the lung-book; but as we have seen, it is not so. Locy has correctly described the formation of the lung-book lamellæ. He says that the lungs arise from infoldings; but he is silent about the place where these infoldings arise.

In the basal part of the second abdominal appendage on the interior side, another ectodermic invagination is produced. It assumes the shape of a deeply invaginated tube and remains in this condition till after the time of hatching. The appendage itself is not invaginated and becomes from this time gradually shorter.

It is very probable that the lung-books were derived from the gills of some aquatic arthropodous animal such as Limulus, for the lung-books are nothing more than the lamellar branchiæ of Limulus sunk beneath the body surface. The tubular trachea may afterwards have been derived from the lung-books. The branchial lamellæ of Limulus are formed as outgrowths of the ectoderm at the lower (posterior) surface of abdominal appendages, and those of spiders are also produced really in the lower surface of the first abdominal appendage (in the dipneumonous spider). Hence, I think that the spider with two pairs of lung-books is the most primitive one, and the one with one pair of lung books and the other pair transformed into the tubular trachæ is more primitive than the spider with only one pair of lung-books. I cannot agree with the view of some authors who maintain that the lung-book is derived from a cluster of tracheæ.

The third and fourth pairs of the abdominal appendages are modified into spinning mammillæ (Pl. XV, Fig. 34). At the distal end of each of these appendages a solid proliferation (*sp. gl.*) of ectodermic cells is formed. This becomes the spinning gland. Spiders have generally three pairs of spinning mammillæ, two of which are modified abdominal appendages, while the remaining one is added very late, after the hatching of the embryo. The primitive spider must have had only two pairs of spinning mammillæ. Some tetrapneumonous spiders have only two pairs.

Laurie (1892) accepts MacLeod's thory "in its main lines," but suggests that "the lung-books of the Arachnids were probably derived from a series of paired plate-like appendages, not united in the middle line by a gradual fusion of their edges with the abdominal walls of the body."

Bernard (1892) thinks the fascinating and seductive theory of MacLeod and others will have to be "given up in view of the great morphological difficulties which they involved" (Spengel's Zool. Jahrbuch, 1892), the main reason he gives being that in Galeodes it is difficult to believe that the thoracic and abdominal stigmata had a separate origin.

If now we return to Metschnikoff's description and figure of the mode of origin of the book-lung of the scorpion, it will be seen that, as he states, the stigmata arise directly under the temporary leg, as seen in his Fig. 12, Taf. XVI. The invaginated portion, then, does not represent the entire leg, but a part of it, possibly the epipodal, which represents the branchial or outer division of the gill-bearing leg of Limulus. The inner portion of the scorpion's leg then disappears by absorption.

THE DEVELOPMENT OF THE BRANCHIAL LEGS OF LIMULUS.

Our own observations on the branchial legs are fragmentary and have been made on embryos of a stage nearly that represented by Fig. 20, Pl. IV, of our first memoir, this stage being marked by the appearance of the third pair of abdominal limbs.

At this stage the appendages are very thick and like loose flattened sacs, and the abdomen beyond is loose and baggy.

My sections were sagittal ones, and, though made on freshly preserved material, were not so satisfactory or desirable regarding histological details as could be desired.

The "operculum" or first pair of abdominal legs are thicker, though but little longer, than the second pair. Seen in section on the slide, the limb is simply sack-like, with no internal structures or any hairs externally, though the musculature is in part developed. The second pair alone bears the gills; the appendage itself is nearly, if not quite, as long as the first pair, though not so thick. The muscles are distinctly developed. The legs each bear five leaf-like sacs (Figs. 2, 3, 4, 5, *a*, *b*, *c*, *d*, *e*), which are from one-half to two-thirds as thick as the leg itself, and gradually diminish in length, the outside one, which is the last to be developed, being minute, the two basal ones being of nearly equal length and from a third to a fourth as long as the entire limb. The gills are hollow, but lined with hypodermic cells, though the nuclei are not visible, this being perhaps due to the mode of preparation or of sectioning. The limits of the cells themselves are not visible, and from the thick protoplasmic, very transparent lining, which does not readily stain with the alcoholic carmine, more or less conical, pointed processes extend out into the cavity, and sometimes meet similar processes from the opposite side, forming slender pillars or trabeculæ. These thin protoplasmic partitions, though suggesting the regular transverse septa of the spider's lung-lamellæ, described and figured by MacLeod * and by Locy, are by no means so distinctly developed and are not morphological equivalents to them. The short outer leaves are more or less crumpled, with very thin walls.

The larvæ (Pl. XX, Figs. 6, 6*a*, 6*b*, 6*c*) were prepared, sectioned, and mounted in the same manner as the embryos, but the histological structure of the gill-sacs is now much more definite and satisfactory to study, the hypodermis consisting of distinctly marked cells, with large deeply stained nuclei.

The first pair of abdominal legs reach to the end of the abdomen, as already described and figured in my first memoir, and also more elaborately by Dr. Kingsley. They are seen in section to be very thin, being in this respect much as in the adult.

The second pair of legs (Fig. 6*b*, 6*c*, I) is only about half as long as the first pair. The hypodermis towards and at the base consists of large distinct columnar cells, becoming at the base double. Under the hypodermis, at the base of the appendage, is a double series of rounded, quite large cells; while within the interior is filled with nuclei of irregular size, arranged in short streaks, the cell-walls being obliterated. Pl. XX, Figs. 6*a*, 6*c*, show five leaves or gill-sacs lined with a hypodermis as distinct as in the appendage itself. The basal or first-formed gill-sac is nearly twice as long as the second one; the succeeding ones diminish in length, the fifth one being a simple fold.

There are no traces of any transverse septa comparable with those of the lung-leaves of Arachnida.

The third pair of appendages (Pl. XX, Fig. 6*c* III) is now simple, not standing out free from the surface, but lying under the second pair. The cells of the hypodermis are large and round, not closely packed and columnar, as in the second pair. As yet there are no rudiments of the gill-sacs. The cells which are to give rise to them are as yet in an indifferent state, and this condition of things, shown in our figure, strongly recalls the structure of the embryonic appendages destined to form the book-lungs of the spider represented by Kishinouye. (His Fig. 34, 1 abd. app., 2 abd. app., etc.)

This striking similarity in the shape of the deeply stained nuclei and their arrangement just as the book-leaves or sacs are beginning to be formed shows the close similarity of the mode of origin of the appendages in question of the two groups.

Further observations, both on the embryonic as well as larval structure of Limulus and of Arachnids, are now needed to finally clear up the points which have been raised by recent investigations. But Kishinouye's statements and his Fig. 34 have, more than any others, convinced

* MacLeod has studied the gills of the adult Limulus by sections, and finds that the inner cavity of a gill-sac is lined entirely with hypodermic cells and has fibrous pillars, besides numerous multicellular glands opening on its upper surface. On the other hand, a single leaf of a spider's lung has within it numerous transverse pillars (querpfeiler), each with two nuclei, and a peculiar modification of the plasma, which perhaps acts as a muscle to contract the cavity of the leaf. Other cell elements are wanting. (Arch. Biol. v., 1–34, 1884).

me that the book-leaves of Arachnida are really the homologues of the thin gill-sacs of Limulus, and that the two classes have probably originated, if not from a common ancestor, yet from those standing very near each other.

In closing, we would make a suggestion in the way of an explanation of the points of resemblance of the Podostomata (Merostomata and Trilobites) to the Phyllopod Crustacea, especially Apus. Even so strong an opponent of the idea that there is any close affinity between Apus and Limulus as Lankester, allows that there are some points of resemblance between Apus and Limulus, "the most important being the jaw-processes at the base of all the ambulatory limbs, and the presence of a pure archicerebrum in both genera."

We have shown that the brain of Limulus, though roughly speaking an archicerebrum, is very different from that of any Phyllopod. Still the points of resemblance between these primitive Phyllopods and the Merostomata are due, perhaps, to the fact that the ancestors of both Crustacea and Podostomata were probably derived from somewhat similar Annelid-like ancestors, though by quite independent lines of descent. We would therefore agree with Lankester's conclusion in his essay on Apus, that the points in which Apus and Limulus agree "are probably points in which they both approach the common ancestor of the Arachnida and Crustacea."

But we differ from this able author in supposing that the Merostomata and Trilobites, or at all events the Merostomata, should be merged with the Arachnida, as they have characters, both external and internal, which forbid their being regarded as Arachnids.

We believe, with A. Milne Edwards, that they should form a separate class. There were, then, four lines of development in the Arthropoda (throwing out for the present the Lingnatulina and Tardigrada), viz: The Podostomatous line, the first to be struck off from the Annelidan stock (the trilobites being the first forms to appear), second the Arachnidan line; third, the Crustacean line, nearly coeval with the first or Podostomatous; and the fourth, the line culminating in Myriopods, Scolopendrella, and insects; and it is safe to suppose that the terrestrial tracheate groups of Arachnida, Myriopoda, and insects were later products than the marine, aquatic branchiate classes, *i. e.*, the Podostomata and the Crustacea.

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LETTERING OF THE PLATES.

Ab I, Ab II, Ab III, first, second, and third pairs of abdominal appendages of the embryo. Pl. XVII.
an., anus (=proctodæum). Pl. XVII.
ant. st., anterior branch of the stalk of the mushroom body.
1st app. gang., ganglion of the first pair of appendages.
app.' n., nerve of 1st pair of appendages ("cheliceral nerve").
asc. st. m. b., ascending branch of the stalk of the mushroom body.
b. c. l., bulb of the cerebral lobe ("*tubercle protocerebrale*" of Viallanes).
br., brain.
c. g. c., *c. g. c'.*, *c. g. c''.*, groups of cerebral-ganglion cells.
ch. c., chromatic cells, small ganglion cells, or aprotoplasmic cells of the mushroom body.
c. l., *cer. l.*, *cer. lobe*, and *cer. gang.*, cerebral lobe or ganglion.
c. ch., "Chiasma," or bundle of twisted nerve-fibers connecting the outer or third with the second division of the lateral-eye lobes ("*Chiasma externe*" of Viallanes).
c. com., *c. l. com.*, and *com. c. l.*, cerebral commissure.
f., sense organ of embryo. Pl. XVII.
f'. f''., bundles of fibers arising from large ganglion cells. Pl. VI.
fasc., fascia or bundle of fibers arising from the ganglion cells.
g. 1st app., ganglion of the first pair of appendages.
i. g. l., inner ganglionic layer of lateral eye lobes.
l., labrum of embryo. Pl. XVII.
lat. h., "lateral heap," or "dorsal organ" of the embryo. Pl. XVII.
lat. eye l., lateral-eye lobe.
lat. eye l'., proximal or first division of the lateral-eye lobes.
lat. eye l''., second or middle division of the lateral-eye lobes.
lat. eye l'''., third or external division of the lateral-eye lobes.
lat. eye n., lateral-eye nerves.
lat. eye n. r., origin or root of lateral-eye nerve.
l. g. c., large ganglion cells.
l. st., lateral branch of stalk of mushroom body.
l. t. n., *l. teg. n.*, lower tegumental nerve of the brain.
m., mouth of the embryo (stomodæum).
m. b., mushroom body or pedunculated body.
m. eye l., median-eye lobe.
m. eye n., median-eye nerve.
m. eye n. c., external lobule of the median eye-lobes.
m. eye n. r., root of median-eye nerve.
m. n., unpaired fronto-median nerve situated between the lower tegumental nerves.
œ., œsophagus.
n^1. to n^3. neuromeres, or ganglia of the embryo.
œ. com., œsophageal commissure or connective.
post. œ. com., postœsophageal commissure. Plate XVI.
pr. œ. com., præsophageal commissure. Plate XVI.
st., stomach. Pls. XVIII and XIX.
st. mb., stalk of the mushroom body.
s. m. g. c., *s. m. g. c'.*, small ganglion cells forming the ruffle-like masses of the mushroom body.
teg. n., tegumental nerves of the œsophageal ring.
u. teg. n., upper tegumentary nerve.
I, II, III, IV, V, VI, the six pairs of cephalothoracic appendages.
I g., *VI g.*, ganglia of the first and sixth pair of appendages.

EXPLANATION OF PLATES.

Pl. I. Figs. 1–7. Horizontal sections through the brain of the adult Limulus passing from above downwards, involving the lateral eye and median-eye lobes. In Fig. 5 the section involves the upper part of the median-eye lobes (*m. eye l.*); the ruffle-like masses of the mushroom bodies (*m. b.*) are seen in Fig. 1, on the right side, this and all the sections of this brain having been cut a little obliquely, the brain not having been evenly placed in the object-holder.

Pl. II. Figs. 7*a*, 7*b*, 8–10. Horizontal sections, continued, passing downwards through the same lobes. Fig. 7*a*, represents the same section as Fig. 1, but enlarged; *ch. cl.*, the internal thin sheet of chromatic or small ganglion-cells situated at the distal end of the external chiasma of the lateral-eye lobe. (Compare Pl. VII, Fig. 2*a*, *ch. cl.*). Fig. 7*b*, the external or third division of the same lobe ("*lame ganglionnaire*" of Viallanes), still more enlarged showing the inner sheet of chromatic cells (*ch. cl.*) and the fibrillæ arising from them. Fig. 8, from a section lower down, passing through the median-eye lobes (*m. eye l.*) and involving on the right side the first and middle divisions of the lateral-eye lobe; *m. b.*, the upper masses of chromatic cells of the mushroom body; *app'. n.* nerve of the first pair of appendages; *m. eye n.*, median-eye nerves fused into one. Fig. 9, the same a little lower down. Fig. 10, details of the median-eye lobes; *m. eye n. r.*, root or origin of the median-eye nerves, seen to be separate from its fellow, and to arise from near the external aspect of the lobes, while still more externally arise the lateral projection of the lobes (*m. eye n. e.*) the fibers arising from a special mass of chromatic cells. (See also Pl. VII, Fig. 1, *m. eye n. r.*) The space between the roots of the median-eye nerves is seen to be filled with both large and small (chromatic) ganglion-cells; *c. com.*, the cerebral commissure, the fibers of which appear to arise from the crescent-shaped mass of chromatic cells.

Pl. III. Figs. 11–15. Horizontal sections, continued, passing through the median-eye lobes. Fig. 11. This section passes through the cerebral commissure (*c. l. com.*) with its crescent-shaped mass of chromatic ganglion cells. Fig. 12. The œsophageal commissure connecting the cerebral commissure with the œsophageal ring is seen on the right side of the section.

Pl. IV. Figs. 16–19. Passing through the cerebral lobes. In Fig. 17 is seen a portion of the stalk of the mushroom body (*st. m. b.*). Fig. 18. Enlarged view of a bundle of fibers on right side of the cerebral lobes, arising from a group of chromatic cells. Fig. 19. Enlarged view of a similar area in a section below.

Pl. V. Figs. 20–22. Sections passing through the lower part of the cerebral lobes and their "nucleogenous bodies," forming the cortical portion of the numerous branches of the mushroom bodies. In Fig. 21 is seen the basal portion of the stalk of the left mushroom body, with one of its lateral branches (*l. st.*) and the anterior branch (*ant. st.*). (Plate XXXI is photographed from a drawing of a section lower down, below the cerebral lobes; the clear spaces being the fibrous substance of the branches of the mushroom body which pass down to the base of the brain, and which, with their ganglionic cortices, form the lower third of the brain.)

Pl. VI. Fig. 1. Horizontal section (Nos. 43 and 44) through the brain of a small Limulus, the body about 2 inches long, exclusive of the caudal spine, and showing the entire lateral eye lobes; *f'.*, a bundle of fibers arising from the large ganglion cells in the median-eye lobes and passing backwards into the cerebral lobes, meeting the fibers of its mate; *f''.*, a second bundle of fibers meeting those of its opposite bundle in the middle of the cerebral lobes; *ch. c.*, sheet of chromatic cells in the external or third division of the lateral-eye lobes. At this stage the ganglia of the first pair of appendages are seen to be entirely distinct from the brain proper, not showing the tendency to fuse with the base of the brain, seen in old, large examples.

Pl. VII. Figs. 1–3. The same lower down. Fig. 1. Origin of the median-eye nerves; the horseshoe-shaped bundle of fibers inclosing the large and small ganglion cells of the partially fused median-eye ganglia or lobes. Fig. 2. The entire lateral-eye lobe is seen on the right side; *l. g. c''.*, a group of large ganglion cells sending a bundle of fibers backward into the œsophageal commissure. Fig. 2*a*, showing at *e. ch.* the twist or "chiasma" (*sic*) of the fibers connecting the second and third divisions of the lateral eye ganglia, and the sheet of chromatic cells which appear to give rise to the fibers forming the so-called chiasma.

PL. VIII. Figs. 1–4. Horizontal sections of the same. Fig. 1. Section passing through the base of the cerebral ganglia and involving the lower tegumental nerves, or nerves to the sensorial papilla situated in front of the first pair of appendages (probably the "neuropore" of Patten). Figs. 2, 3, and 4, sections passing through the lower branches of the mushroom bodies. Figs. 5, 6, 7, sagittal sections of brain of a small Limulus of the same size as above indicated. Fig. 5, represents a section through the brain passing through the lateral-eye lobe and nerve; also involving the ganglia of the first and of the second pair of appendages, forming the anterior portion of the œsophageal ring. Fig. 6. Section passing through the median-eye lobe and nerve; also the cerebral lobe and the nerve to the first pair of appendages.

PL. IX. Figs. 1–7. Sagittal sections through the brain of an adult Limulus, beginning near one side. In this and plates X to XVI the pink portions represent the cortical masses of small ganglion cells of the mushroom body.

PL. X. Figs. 8–13. The same series continued to the middle of the brain, representing, as before, a selection of the typical sections.

PL. XI. Figs. 1–5, and 7. Transverse (frontal) sections of the brain of an adult Limulus from before backwards.

PL. XII. Figs. 6, 6*a*, 8, 9. The same series continued backwards. Fig. 6*a*. Enlarged view of the left median-eye lobe. Fig. 8. Enlarged view of the median-eye lobes a little further back. The fibers arising from the large ganglion cells pass inward towards the median line of the brain.

PL. XIII. Figs. 10–15. The same series continued backwards.

PL. XIV. Figs. 16, 17. The same series continued. Fig. 18. Transverse section through the brain of a young Limulus, passing through the cerebral lobe, and its commissure; externally is the bulb of the cerebral lobe (*b. c. l.*). From this portion of the cerebral lobes arise the stalk of the mushroom body on each side, sending off descending, lateral and ascending (*asc. st. m. b.*) branches.

PL. XV. Figs. 19, 20. Transverse sections of the same lower down, and involving the œsophagus.

PL. XVI. Figs. 1–12. Transverse sections through brain of a young Limulus, and passing back through the œsophageal ring to the basal portion of the ventral cord. Fig. 6 (section 196), *pr. œ. com.*, pre-œsophageal commissure, connecting the ganglia of the first pair of appendages. It will be seen that in Limuli about two inches in length exclusive of the caudal spine this commissure is quite free from the posterior part of the brain. Compare also Pl. XXXIII. This is apparently the "Commissure deutocerebrale" of Viallanes. See Fig. XIX, p. 312, copied from his work. Figs. 8 to 12 should be turned around, as these sections pass behind the œsophagus. Fig. 8, *post. œ. com.*, represents the second commissure, *i. e.*, the first one behind the œsophagus. Figs. 9 to 12 pass through the beginning of the ventral cord.

PL. XVII. Figs. 1–6. All representing the embryo of a single stage showing the ganglia of the median eyes of the lateral eyes, and the central ganglia. *l.*, labrum. The pit directly in front of the labrum may possibly be the "neuropore" of Patten; n^1 to n^3, the neuromeres, or embryonic ganglia; *f.*, the two pairs of sense or glandular organs visible at this stage; *lat. h.*, the "lateral heap" or dorsal organ.

PL. XVIII. Figs. 1–5. Sections through the larva of Limulus, showing the brain and nerve ganglia. Figs. 6–9. The same of the trilobite stage.

(Compare also the figure of a better section of the larva as a whole in my memoirs published in 1880 in Anniv. Memoirs of Boston Society of Natural History, Pl. III, Fig. 2.)

PL. XIX. Figs. 1–9. Sections through the larva of Limulus.

PL. XX. Figs. 1–6. Sections of the lower part of the body, showing the nervous system and abdominal legs of the trilobite stage. Figs. 6 and 6*a*, 6*b*, 6*c*, sections of the abdominal legs and gill-plates of the early larvæ. Fig. 6, section of the first abdominal leg (operculum), and of the second, bearing five gill-leaves, and the rudiment of a sixth. Fig. 6*a*. The same enlarged. Fig. 6*b* and 6*c*, other sections of the same from the same larva.

All the figures on Plates I to XX have been drawn with the camera by the author.

PL. XXI. From a microphotograph of the section of the brain represented by Pl. I, Fig. 3.

PL. XXII. From a microphotograph of the section of the brain a little below.

PL. XXIII. From a microphotograph of the section of the brain represented by Pl. I, Fig. 6, where the parts are lettered.

PL. XXIV. From a microphotograph of the next section below.

PL. XXV. From a microphotograph of the section represented by Pl. II. Fig 8.

PL. XXVI. From a microphotograph of the section represented by Pl. II, Fig. 10.

PL. XXVII. From a microphotograph of a section still lower down.

PL. XXVIII. From a microphotograph of the second section below Pl. XXVII.

PL. XXIX. From a microphotograph of the section represented by Pl. III, Fig. 12.

PL. XXX. From a microphotograph of the third section below that represented by Pl. III, Fig. 14.

PL. XXXI. From a photograph of a drawing, by the author, of a section much lower down than that represented by Pl. V, Fig. 22.

PL. XXXII. From a microphotograph of a transverse horizontal section through the brain of a young Limulus, passing through the lower part of the cerebral lobes, with the commissure uniting them and the œsophagus behind. Osmic acid preparation. (Section 136.) (The same section is represented on Pl. XIV, Fig, 18.

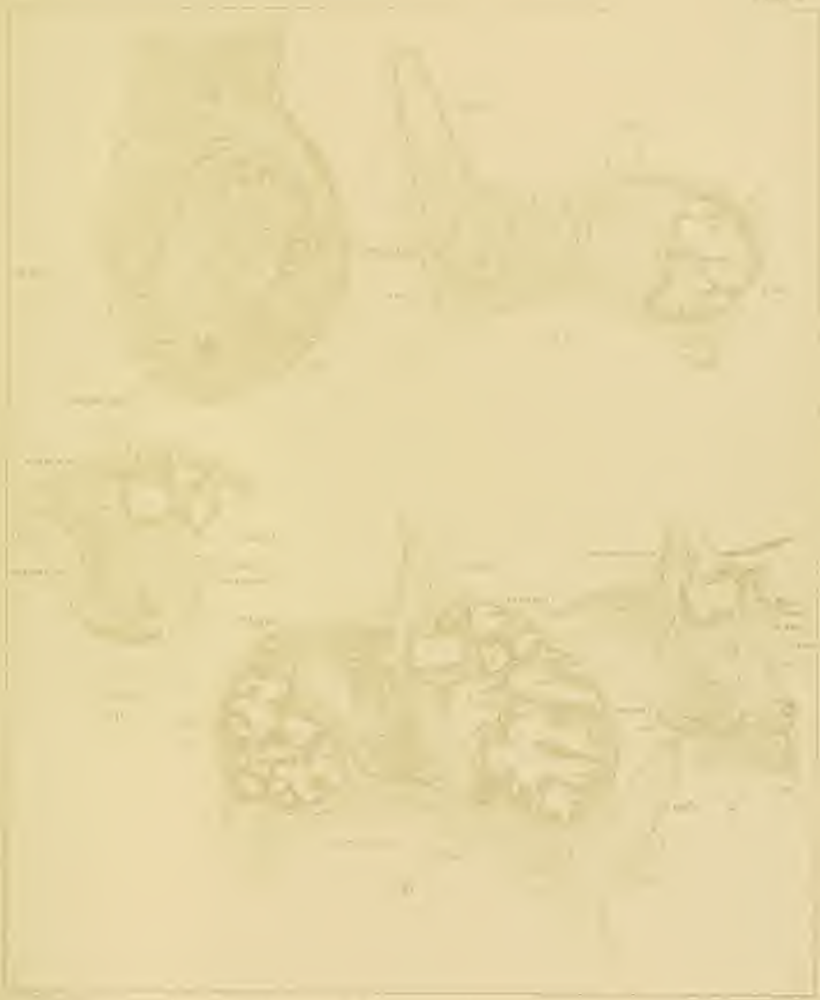
PL. XXXIII. From a microphotograph of a horizontal section through the brain of a young Limulus, involving part of the œsophageal ring and ganglia of the four anterior appendages. (Section 32.)

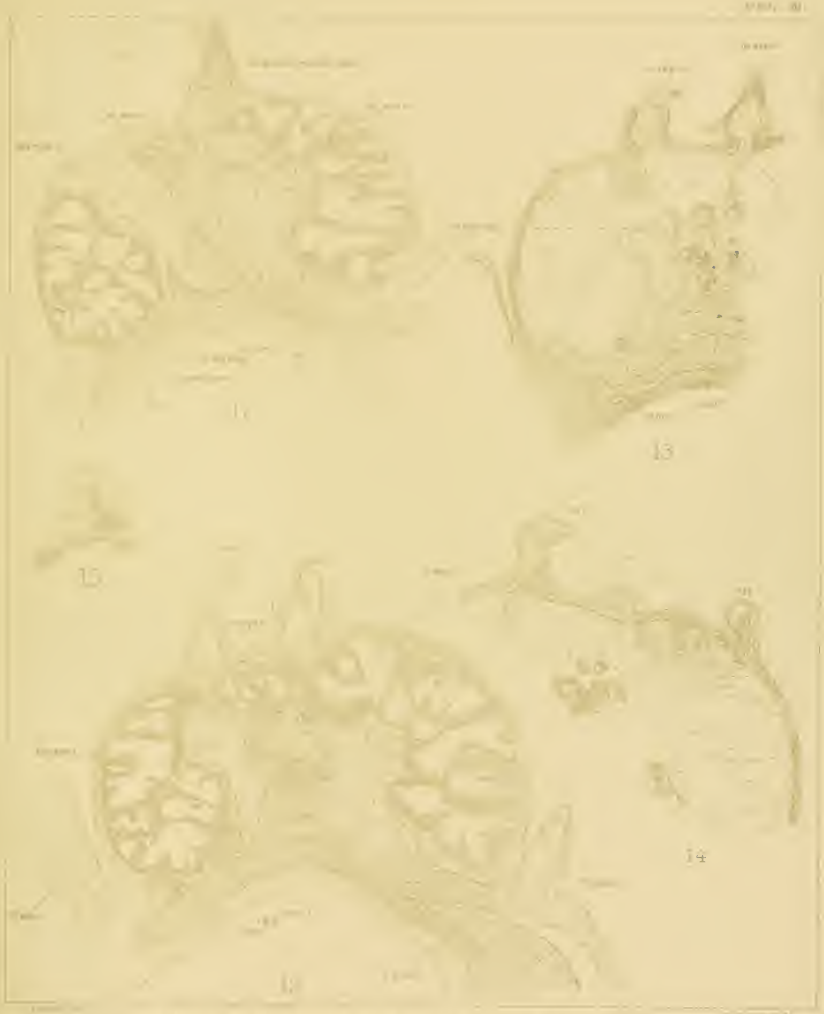
PL. XXXIV. The same, involving the six ganglia on one side of the œsophageal ring and the origin of the connectives of the abdominal portion of the nervous cord. (Section 40.)

PL. XXXV. The same (section 48) made lower down, showing the same ganglia, with their large ganglion cells, and origin of the nerves to the six cephalothoracic appendages.

PL. XXXVI. Sagittal section through the brain of a young Limulus, showing the dark masses of chromatic ganglion cells contrasting with the fibrous and punctured substance; *con.*, connective passing to the œsophageal ring. (Section 39.) All the microphotographs were taken by Dr. W. M. Gray, U. S. A.

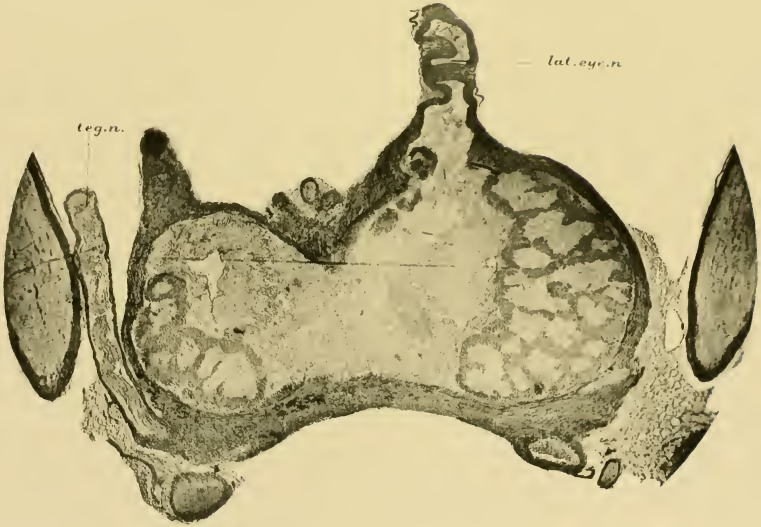
END OF VOL. VI.





Horizontal Sections of the Brain of Testudo polyphemus.

PLATE XXI.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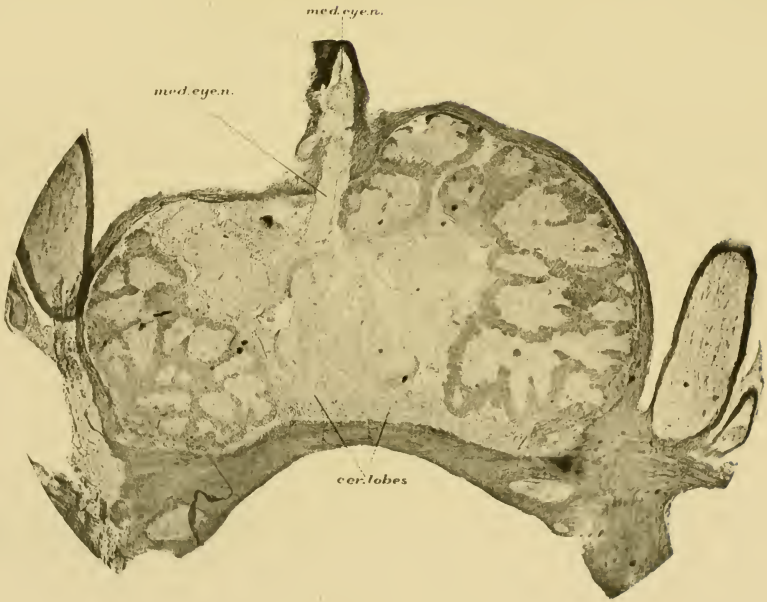
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PLATE XXV.

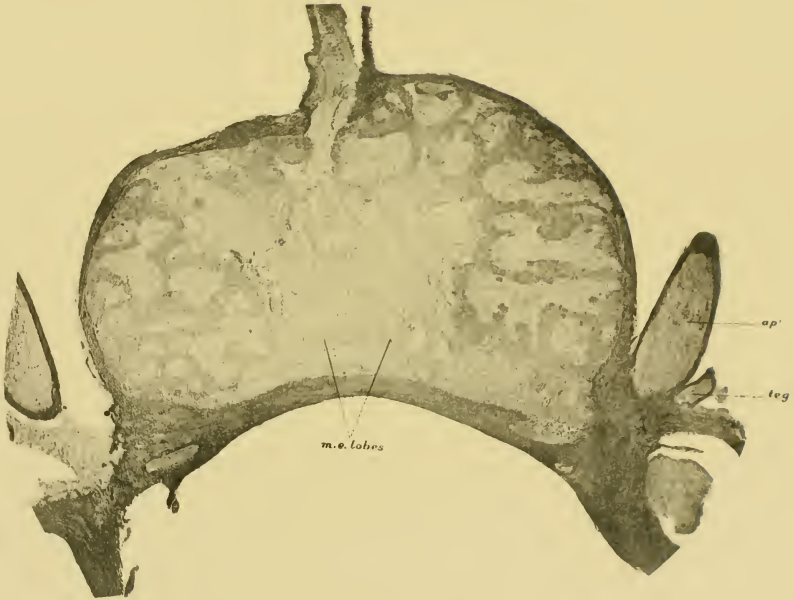


PLATE XXVI.

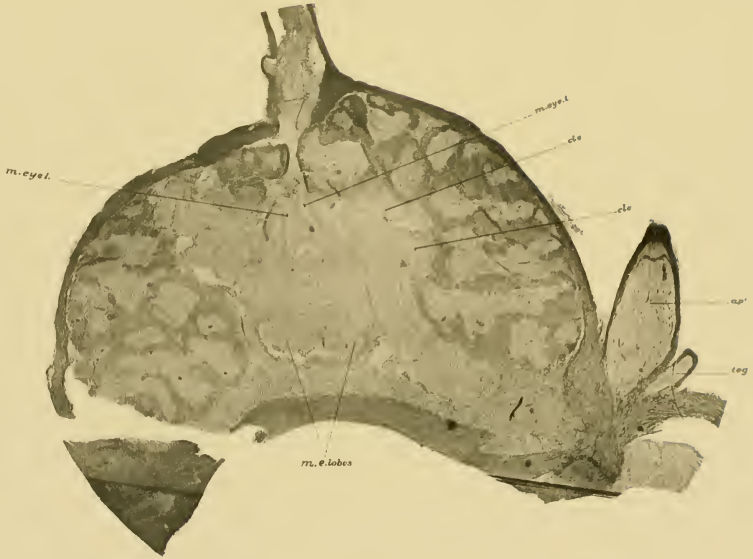
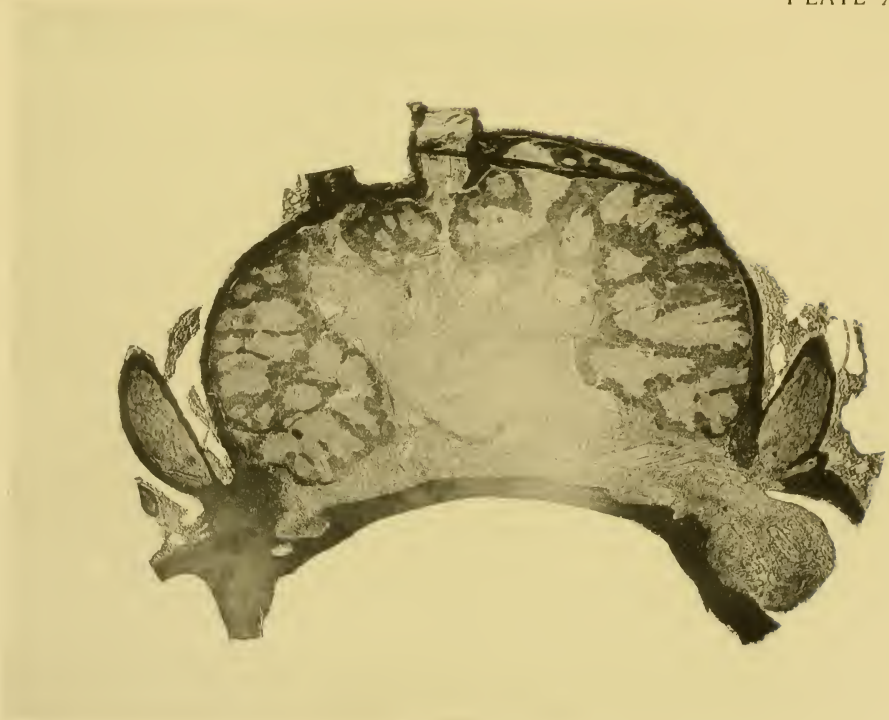


PLATE XXVII.



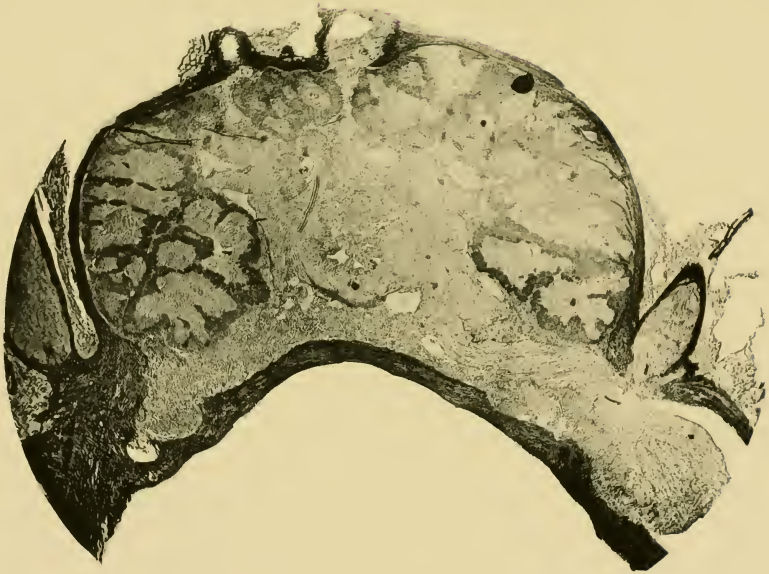
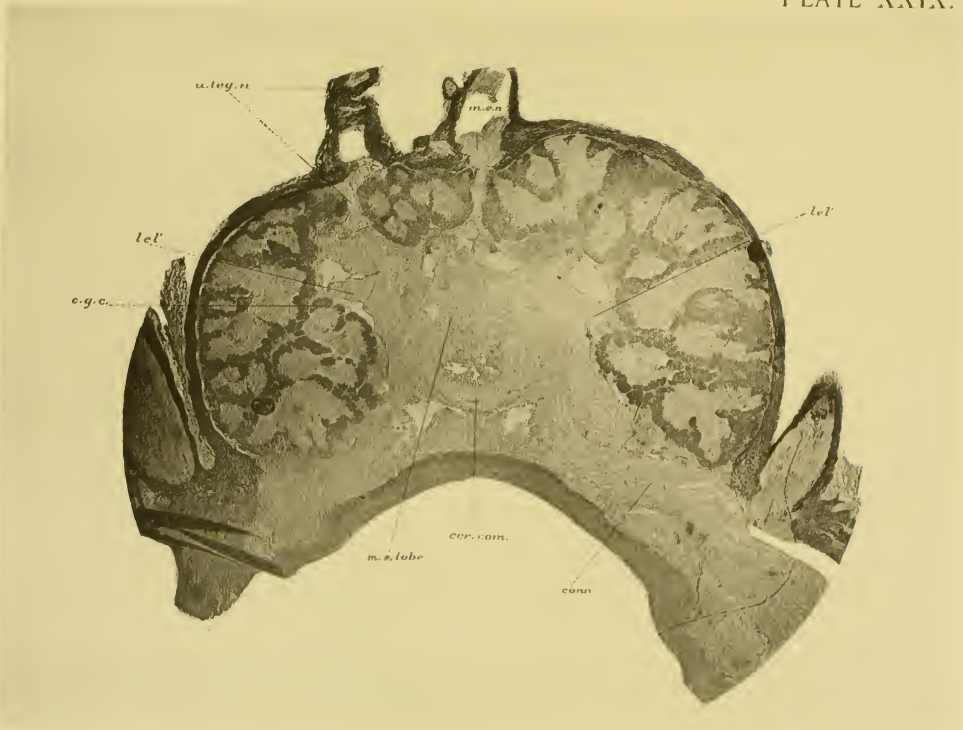


PLATE XXIX.



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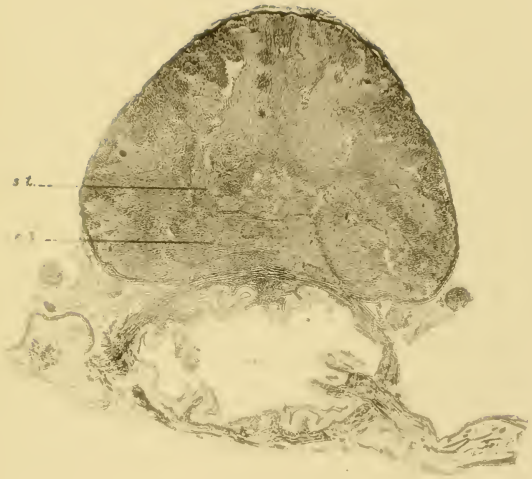
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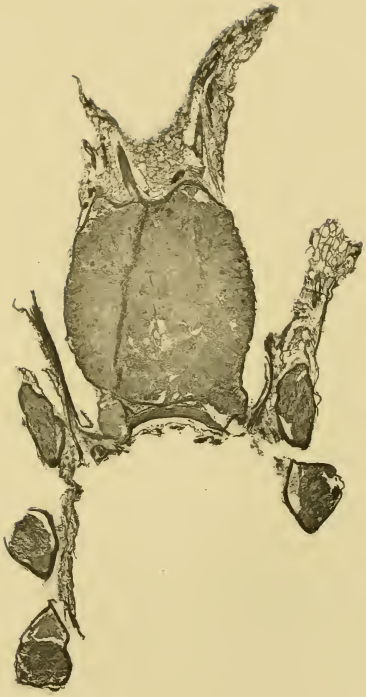

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PLATE XXXVI.

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